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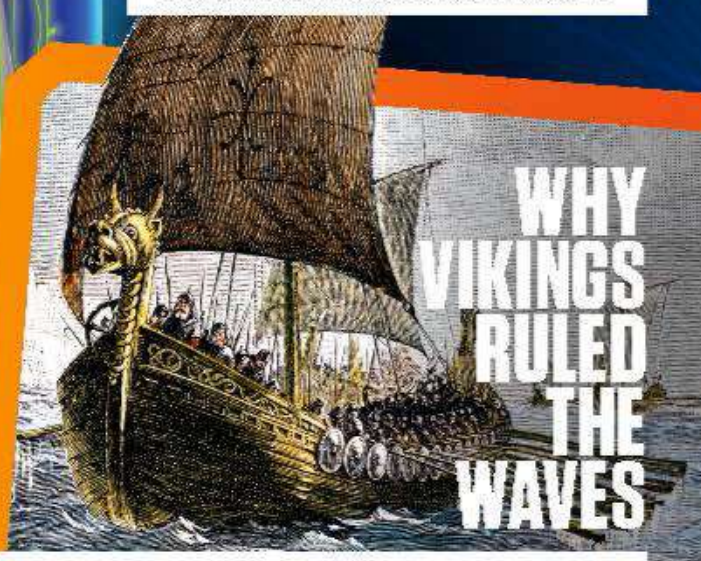

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# WELCOME

Issue 175

"Your immune system saves your life on a daily basis"

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**Your immune system explained**

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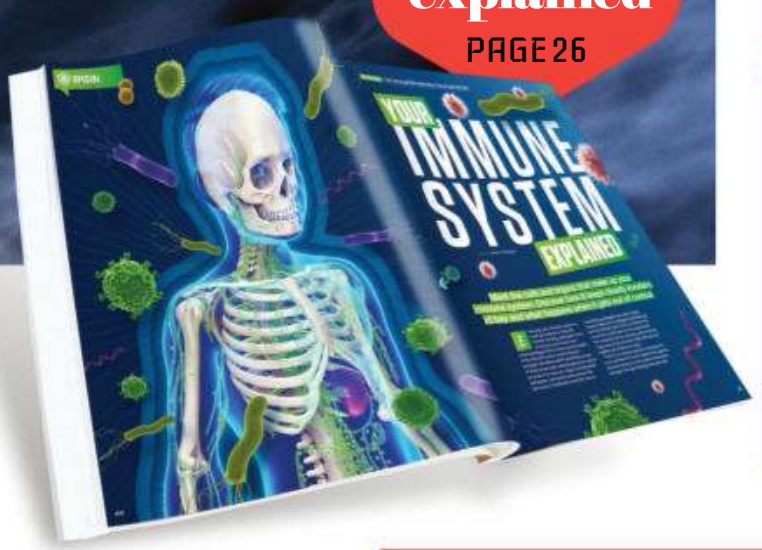
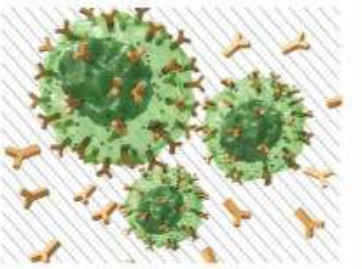



You probably think about your immune system even less than you do your digestive system, which in a healthy person will make itself known several times a day with a grumbling sound around meal times. By contrast, your immune system works quietly and continuously in the background, literally saving your life on a daily basis from germs, viruses and other nasty microscopic organisms that constantly seek to invade your body and make you sick. It's a highly complex network of cells and organs that we still don't fully understand, a system that, when it goes wrong, can be as big a threat to us as the invaders it protects us from. Discover what immunity is and how our bodies fight off infection in this issue's cover feature. Enjoy!

**Ben Biggs**
EDITOR

## HIGHLIGHTS



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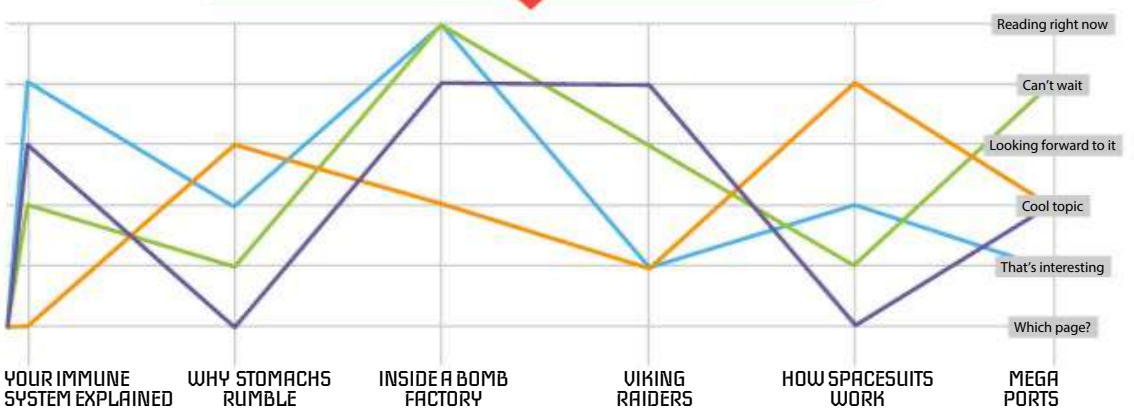

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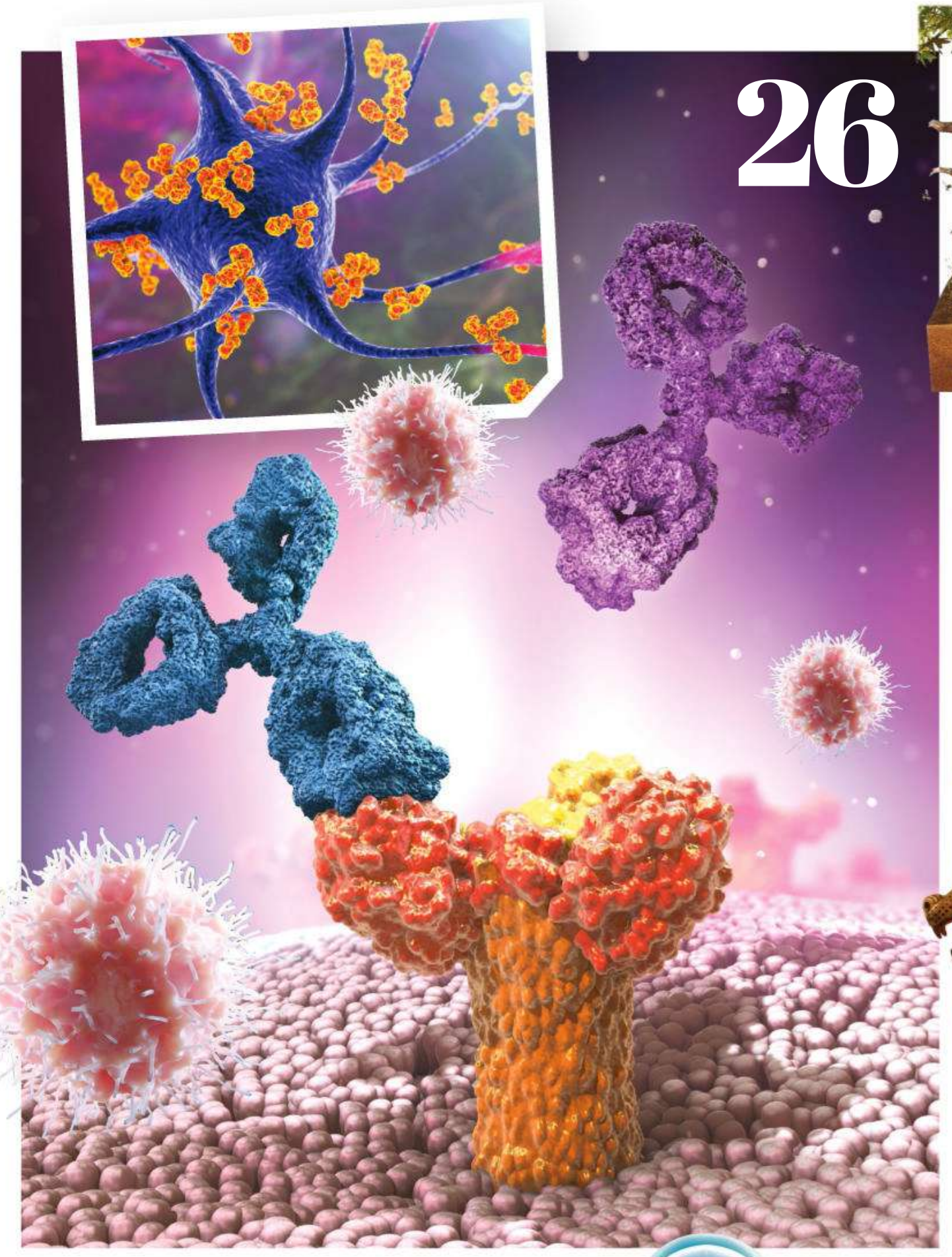

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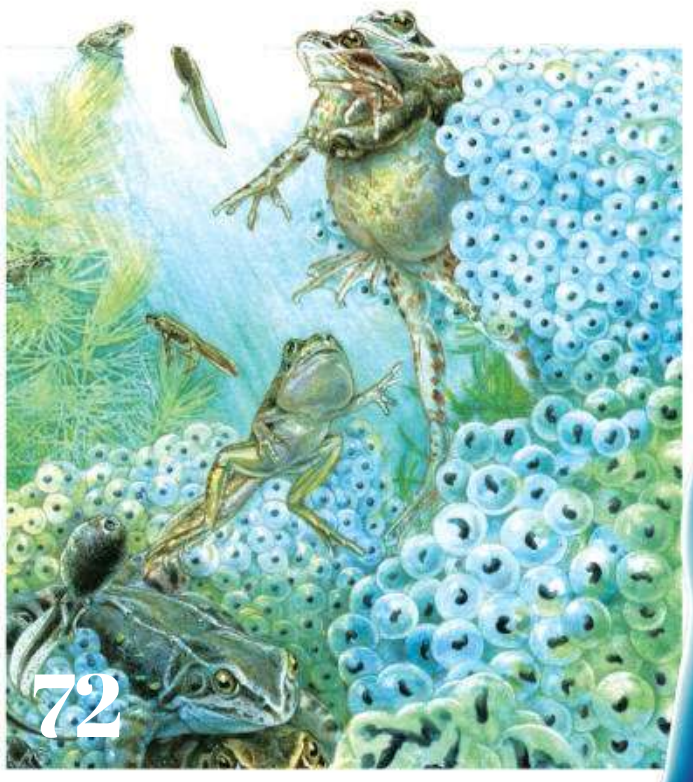

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## Underwater pests

These aquatic parasites weave themselves into the bodies of fish and frogs. Known as *Gyrodactylus salaris*, these tiny pests are only 0.5 millimetres in length and latch onto the surface of an aquatic species to feed their skin, mucus and fins. They do this using an organ called an opisthaptor, a webbed mouth with penetrating hooks around the perimeter.

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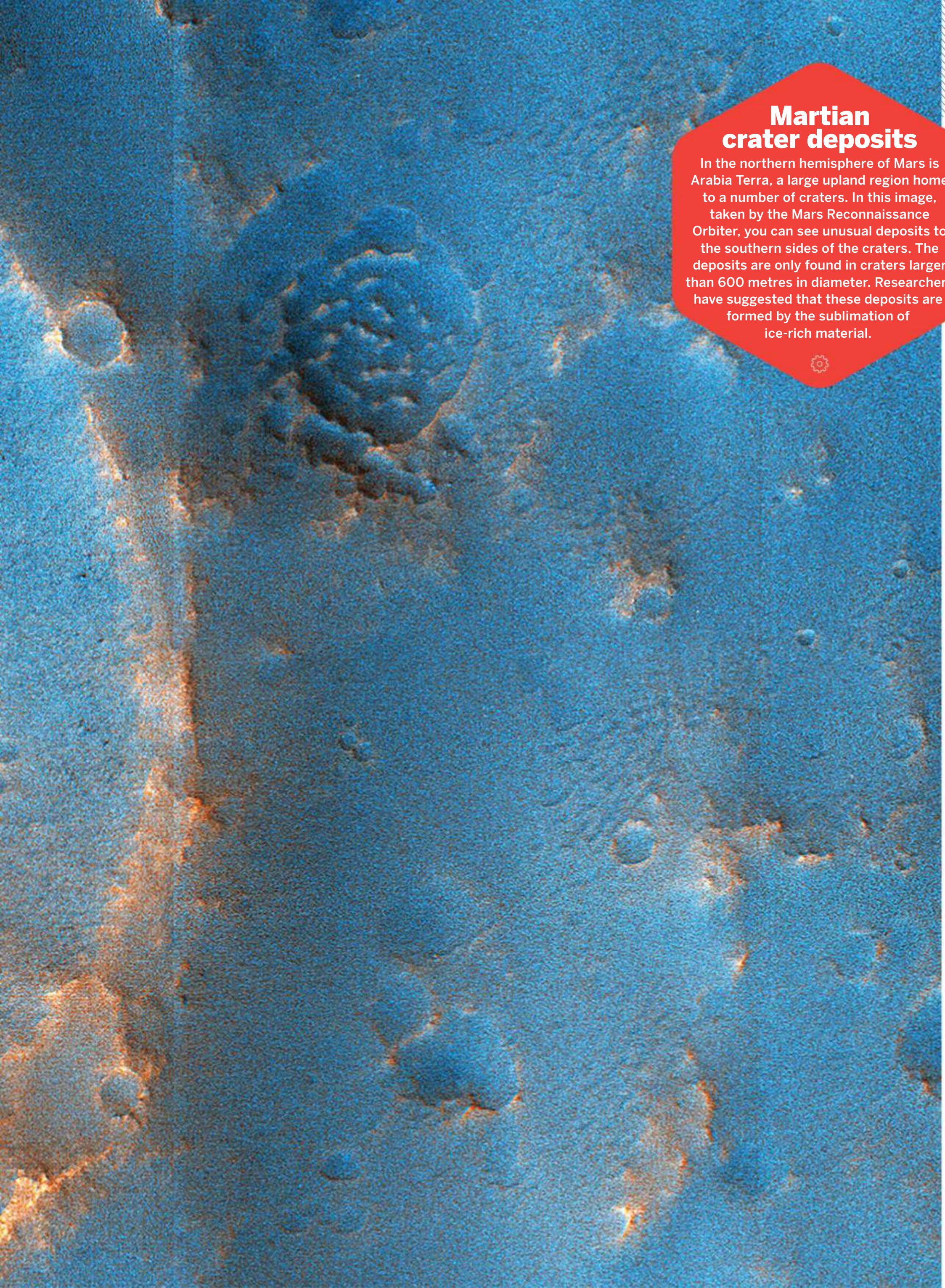


## Martian crater deposits

In the northern hemisphere of Mars is Arabia Terra, a large upland region home to a number of craters. In this image, taken by the Mars Reconnaissance Orbiter, you can see unusual deposits to the southern sides of the craters. The deposits are only found in craters larger than 600 metres in diameter. Researchers have suggested that these deposits are formed by the sublimation of ice-rich material.

© NASA/JPL-Caltech

# Southern sea lions

A colony of South American sea lions (*Otaria flavescens*) enjoy the warm waters of Golfo Nuevo in Argentina. These marine mammals spend their time hunting for octopus, crustaceans and penguins. As social creatures, they remain in large groups of both males and females. The males, known as bulls, will fight to the death to protect their territory if it's intruded upon by outsiders.

© Getty

# Inside a dwarf galaxy

The James Webb Space Telescope has peered into one of the Milky Way's closest dwarf galaxies, the Small Magellanic Cloud (SMC). Around 200,000 light years away, the SMC contains a star-forming region known as NGC 346. Researchers are using Webb's view of NGC 346 to learn how the star-formation process in the SMC works and if this is different from the way stars form in the Milky Way.

© NASA, ESA, CSA, STScI, A. Pagan (STScI)

# GLOBAL EYE

Showcasing the incredible world we live in

A schematic of Earth's hot inner layers. New research finds that the uppermost layer of the mantle is partially melted

PLANET EARTH

# Earth's mantle has a gooey layer

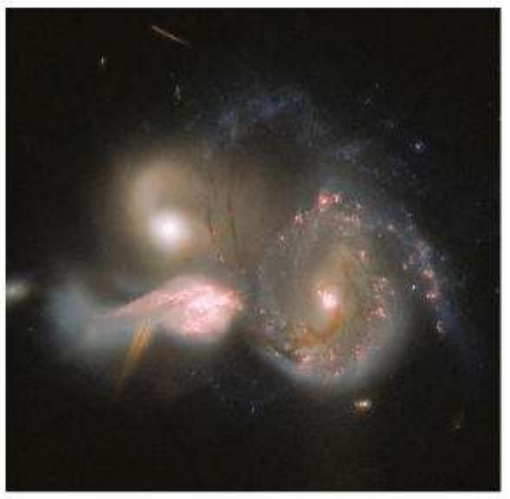
WORDS **STEPHANIE PAPPAS**

Most of Earth's mantle is hot but solid, with rocks that deform slowly rather than cracking like the cooler rocks of the crust do. But new research finds that around 93 miles below Earth's surface, there's a worldwide layer of melted rock. The discovery of this gooey layer will help researchers better understand how the tectonic plates 'float' on top of this mantle layer. The melted rock is in the asthenosphere, the upper layer of the mantle that sits between about 50 and 124 miles below Earth's surface. The only way to peer into this layer of the mantle is with seismic waves from earthquakes. Researchers can detect the waves at seismic stations set up around the world, looking for subtle changes in the waveforms that indicate what kinds of materials the waves travelled through. Previously, researchers knew from these types of studies that some parts of the asthenosphere were hotter than others, and patchy areas of melt had been detected. But little was known about how deep and widespread the melt was.

To find out, Junlin Hua, a postdoctoral researcher in geosciences at the University of Texas at Austin, collected data with his colleagues from thousands of seismic waves detected at 716 stations around the world. They found that rather than holding small areas of melt, the asthenosphere appears to contain a partially melted layer that extends around the globe, under at least 44 per cent of the planet. This area is broadly distributed across the globe and could be much larger, the researchers found, because they were unable to probe under the ocean, which is likely to overlay a layer of melt and which takes up much more area than the continents.

Oddly, though, this melted layer doesn't seem to affect the movements of the tectonic plates. The researchers found that the areas of melt did not affect the mantle's viscosity, or tendency to flow. "[That] melted rock, in addition to solid rock, is not much easier to be deformed than those solid rocks alone," Hua said. "So counterintuitively, those melts, though present, won't affect how easily tectonic plates can move above the asthenosphere." This is useful information for building computer models of how the plates move. "We can't rule out that locally melt doesn't matter," said Thorsten Becker, a geophysicist also at Austin and one of the authors of the study. "But I think it drives us to see these observations of melt as a marker of what's going on in the Earth, and not necessarily an active contribution to anything."

But there's still more work to be done to map out this melty mantle layer. "In this study, we are mainly using seismic instruments on continents, and though we have also used some instruments from ocean islands, there are certainly some degrees of data gap in the ocean," Hua said. "A nice follow-up study would be using other types of data or seismic instruments located on ocean bottoms to bridge this gap."



Three galaxies in the constellation of Boötes imaged by Hubble as they head for a collision

SPACE

## HUBBLE SPOTS GALAXIES ABOUT TO COLLIDE

WORDS **ROBERT LEA**

**A stunning new image from the Hubble Space Telescope shows three galaxies heading for a collision and merger. While galactic collisions are fairly common, this one is rare because each of the trio of galaxies is currently in the throes of birthing new stars. The three galaxies, seen in the constellation of Boötes, will eventually merge to form a single large galaxy. In the process, the spiral structure the galaxies now exhibit will be wiped out as a result of gravitational interactions between the trio.**

**The three galaxies, collectively known as SDSSCGB 10189, are close enough to appear to be merging. The shapes of the galaxies are already distorted, and strands of gas and dust can be seen linking them. Within SDSSCGB 10189, the three large star-forming galaxies are just 50,000 light years apart from each other. While this may seem like a vast distance that doesn't carry much danger of collision, in cosmic terms it's very close. Andromeda, the nearest galaxy to our Milky Way, is over 2.5 million light years away.**

**The merger of SDSSCGB 10189 could result in the birth of one of the largest and most massive galaxies in the universe, which astronomers call brightest cluster galaxies. SDSSCGB 10189 could finally shed light on the mystery of how and when these massive bright galaxies form.**

HEALTH

# The first UK child to receive gene therapy for a fatal disorder is 'happy and healthy'

WORDS **NICOLETTA LANESE**

A 19-month-old girl named Teddi recently became the first child in the UK outside a clinical trial to receive a new gene therapy for metachromatic leukodystrophy (MLD), a fatal genetic disorder. Roughly six months out from treatment, Teddi is a happy and healthy toddler showing no signs of the devastating disease she was born with. The genetic disorder MLD disrupts cells' ability to break down sulfatides, fatty material used to insulate the wiring that runs through the white matter of the brain and much of the nervous system beyond the brain. Sulfatide buildup destroys brain and nerve cells, resulting in cognitive problems, a loss of motor control and sensation, seizures, paralysis and blindness. Eventually, the disorder leads to death.

Typically, MLD treatment is aimed at managing symptoms of the disease, although several experimental therapies, including bone marrow transplants and cord blood stem cell transplants, have sometimes been used to slow the disorder's progression in infants. The new gene therapy, called Libmeldy, was only recently cleared for use by the National Health Service (NHS) and works by inserting into the body working copies of the genes that are faulty in MLD, thus restoring the ability to break down sulfatides. Libmeldy is made using stem cells that are derived from a patient's blood or bone marrow and can give rise to different types of blood cells. These stem cells carry the new, functional genes into the body, where they give rise to white blood cells that travel through the bloodstream.

**Did you know?** White matter is found in deep tissues of the brain

In clinical trials, Libmeldy offered clear benefits to infantile and juvenile patients who hadn't yet developed MLD symptoms; these patients were able to break down sulfatides at normal rates and showed typical patterns of motor development.

The benefits of the therapy seem to last several years, but at this point "it is not yet clear whether it will persist life-long, and extended follow-up is needed," the European Medicines Agency noted. Teddi and her sister Nala, age three, were both diagnosed with MLD in April 2022. Unfortunately, Nala wasn't eligible for Libmeldy because she'd already developed symptoms of the disorder. Teddi had her stem cells extracted in June and received her new modified stem cells in August.

A young girl in the UK recently received a new gene therapy for a fatal inherited disorder

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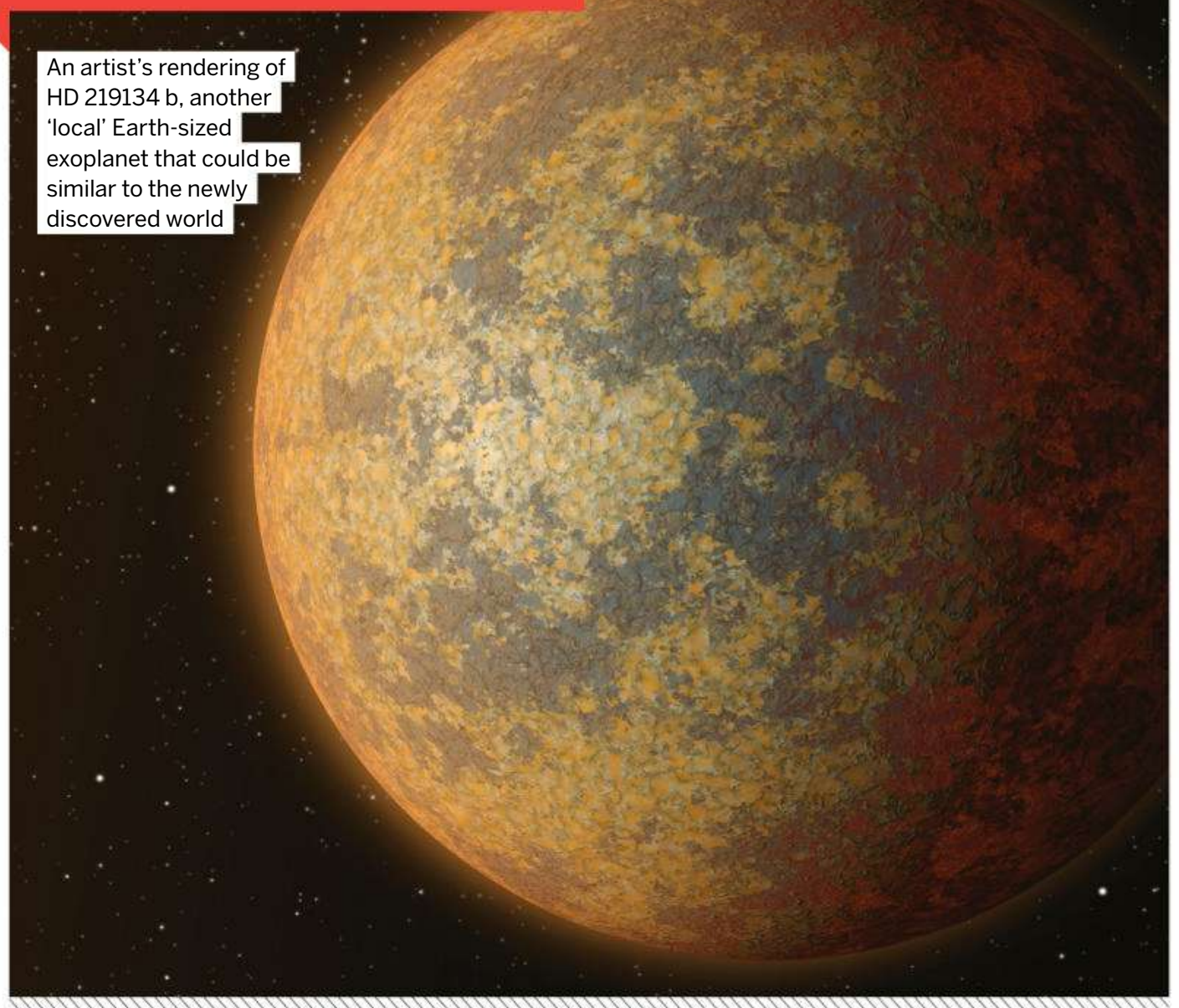


An artist's rendering of HD 219134 b, another 'local' Earth-sized exoplanet that could be similar to the newly discovered world

SPACE

# Earth-sized exoplanet spotted just 72 light years away

WORDS **STEFANIE WALDEK**

An international team of researchers searching for transiting exoplanets has made its latest discovery: an Earth-sized body just 72 light years away from us. K2-415 b, as the newly discovered world has been named, orbits the nearby red dwarf star K2-415. Researchers identified the exoplanet in the data of NASA's now-defunct Kepler space telescope, its secondary mission K2 and its successor, the Transiting Exoplanet Survey Satellite. While K2-415 b isn't the closest known exoplanet to Earth, it is one of our close neighbours on a cosmic scale. And it's a particularly intriguing exoplanet for astronomers to study.

"The K2-415 system is unique in that K2-415 is one of the coolest or lowest mass stars known to host an exoplanet," said Teruyuki Hirano of the Graduate University for Advanced Studies in Japan. In fact, there are only four stars cooler than K2-415 that are known to host at least one exoplanet, including the famous TRAPPIST-1, which has seven known exoplanets. "One motivation for investigating the planets around such low-mass stars is to understand and clarify whether those planets form and evolve just like the planets around solar-type stars," said Hirano. Solar-type stars are stars akin to our Sun. Red dwarf stars, on the other hand, are far cooler and much smaller. K2-415 is thought to have a surface temperature of about 2,900 degrees Celsius, compared to our Sun's 5,500 degrees Celsius, with a diameter of 0.2 solar radii and a mass just 0.16 times that of the Sun.

Ultimately, the more exoplanets we discover and the more we learn about their star systems, the higher the chance we'll find more potentially habitable exoplanets. K2-415 b is not in the habitable zone of its star – the distance from a star at which liquid water can exist on a world's surface. The exoplanet is extremely close to K2-415, so close that it only takes about four Earth days to complete an orbit. "There is a possibility that there is another planet lurking in the system that sits inside the habitable zone," says Hirano. He now hopes to study K2-415 b further, determining its mass and internal structure. Preliminary estimates peg the exoplanet as about three times more massive than Earth, despite having a radius just 1.015 times that of Earth's. But he also wants to turn to the orbit and architecture of the system at large.

HISTORY

# 16-METRE-LONG BOOK OF THE DEAD PAPYRUS IS DISCOVERED

WORDS **OWEN JARUS**

**Archaeologists in Egypt have found a 16-metre-long papyrus containing sections from the Book of the Dead. The more than 2,000-year-old document was found within a coffin in a tomb south of the Step Pyramid of Djoser at Saqqara. There are many texts from the Book of the Dead, and analysis of the new finding may shed light on ancient Egyptian funerary traditions. Conservation work is already complete, and the papyrus is being translated into Arabic. This is the first full papyrus to be uncovered at Saqqara in over 100 years. The Step Pyramid of Djoser was constructed during the reign of the pharaoh Djoser and was the first the Egyptians built. The area around the step pyramid was used for burials for millennia. Indeed, the coffin that housed the newfound papyrus dates to the Late Period.**

**The Book of the Dead is a modern-day name given to a series of texts the Egyptians believed would help the dead navigate the underworld, among other purposes. While 16 metres is lengthy, there are other examples of Book of the Dead papyri of that length or longer. The discovery was made by a team of Egyptian archaeologists from the Ministry of Tourism and Antiquities, which has yet to release images of the ancient document.**

An illustration from the Papyrus of Ani, which dates to the 19th Dynasty of the New Kingdom, circa 1250 BCE

PLANET EARTH

# The world's deadliest mushroom conquered California with a clone army

WORDS BEN TURNER

The death cap mushroom is a small, green-tinged mushroom that sprouts from the forest floor

The world's deadliest mushroom has been invading California by cloning itself. The poisonous death cap mushroom (*Amanita phalloides*) is an invasive fungus whose fatal amatoxin accounts for more than 90 per cent of deaths from mushrooms worldwide, but how it spread from its European origins to colonise every continent except Antarctica has long been a mystery. Now, researchers have found a reason why: the California version of the death cap can fertilise itself and produce perfect copies, sidestepping the need to mate before wafting its spores over an unconquered region. "The diverse reproductive strategies of invasive death caps are likely facilitating its rapid spread, revealing a profound similarity between plant, animal and fungal invasions," researchers wrote.

Death caps are unassuming mushrooms: the door-knob-sized fungi have a pale green, white or bronze cap; white gills and a silky, skirt-like membrane. The mushroom is said to be pleasant tasting, so when its deadly effects set in 6 to 72 hours later, they often come as a surprise. The mushroom's amatoxin poison enters the liver through the intestinal tract, where it binds to and inactivates enzymes used to make new proteins. With protein production now halted, the liver begins to die, causing nausea and diarrhoea, often followed by rapid organ failure, coma and death.

Scientists think the mushroom was introduced to North America in the late 19th century by tree fanciers, when fungal spores of A. phalloides hitched a ride with the soil-potted seedlings of European trees. In Europe, *A. phalloides* grows by burrowing into the roots of common oak trees (*Quercus robur*) to form a symbiotic relationship known as ectomycorrhiza – taking essential sugars from the trees' roots in exchange for helping them find water and nutrients, alongside intercepting chemical signals from neighbouring trees. By 1938, death caps were found sprouting from the roots of an ornamental oak tree (*Quercus suber*) at the Del Monte Hotel in Monterey, California. From there, the mushroom leaped to wild California live oaks (*Quercus agrifolia*), then to California's native pines, and even to its beech, chestnut, birch, spruce, hornbeam and filbert trees. Soon the mushroom could be found everywhere across the Bay Area and further up the coast, becoming more abundant than it was in its native Europe.

Just how it managed this feat has, until now, been unclear. In Europe, DNA sequencing showed the death caps reproduced sexually. But in the new study, DNA sequences found many of the Californian death caps contained the exact same genetic material as each other and that they could reproduce asexually for up to 30 years. The researchers proposed that in new environments death caps switch on asexual reproduction as a way to gain a foothold, then return to sexual reproduction after successful colonisation. Now that this weird cloning ability has been revealed, the researchers have other questions about the fungal invader. Samples collected in New Jersey and New York showed no sign of asexual reproduction, which could mean it's only triggered at certain times and in certain environments.

© Getty / NASA; JPL-Caltech

# GLOBAL EYE

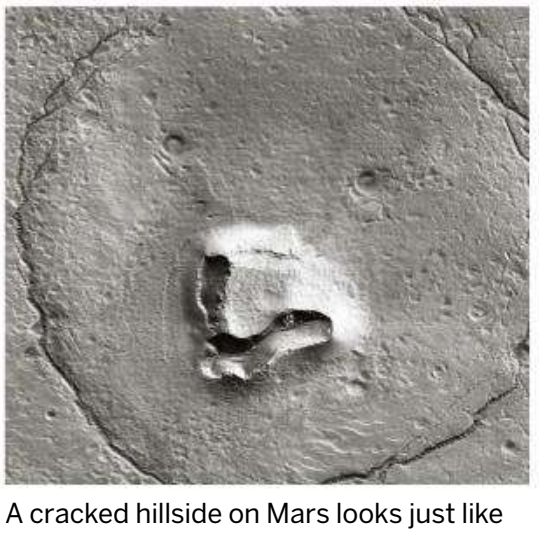
SPACE

## NASA SPIES A 'TEDDY BEAR' IN MARTIAN ROCKS

WORDS **BRANDON SPECKTOR**

**Scientists studying the surface of Mars recently found a piece of the planet smiling back. In an image shared on 25 January, what appears to be the face of an enormous Martian teddy bear, complete with two beady eyes, a button nose and an upturned mouth, grins at the camera of NASA's Mars Reconnaissance Orbiter (MRO). This photo of an uncanny assortment of geological formations was snapped on 12 December 2022 as the MRO cruised roughly 156 miles above the Red Planet. It's likely just a broken-up hill in the centre of an ancient crater. "There's a hill with a V-shaped collapse structure, two craters and a circular fracture pattern," said NASA, "The circular fracture pattern might be due to the settling of a deposit over a buried impact crater."**

**A bear's face emerges from a collection of dusty rocks and crevices thanks to a phenomenon called pareidolia, a psychological tendency that leads people to find significance in random images or sounds. Space provides endless fodder for pareidolia. The newly discovered Martian teddy bear was imaged by HiRISE, which is one of six science instruments on board the MRO. HiRISE has been snapping pictures of the Red Planet from orbit since 2006 and is the most powerful camera ever sent to another planet. More incredible images – and perhaps more cuddly faces – surely await just over the Martian horizon.**



A cracked hillside on Mars looks just like the face of a teddy bear

A new study has shown that free-roaming queen bumblebees are being killed when they enter commercial hives

ANIMALS

## Invading queen bees are taken down by rival workers

WORDS **HARRY BAKER**

Wild, free-roaming queen bees in search of a new kingdom are often lured to commercial hives, where resident workers murder the queens almost as soon as they get through the door. However, it's not all bad news: a new device could help stem the queen bee massacres. Researchers serendipitously discovered the unusual killings while studying how common eastern bumblebees (*Bombus impatiens*) pollinate crops. When the team opened up the commercial-style hives they had set up around the Finger Lakes region of New York, they found that dead wild queens piled up just inside the entrance of every one. On average, each hive had ten dead queens, but the record was 19. Most of the dead queens were *B. impatiens*, but some of the murdered matriarchs belonged to the closely related species *Bombus perplexus*, commonly known as the confusing bumblebee.

The researchers realised that the wild queens, who are naturally drawn to commercial hives because of their bright colours, were likely attempting to usurp the resident queen. In the wild, bumblebee queens can invade the hives of other queens and overthrow them to claim the colony as their own. But because commercial hives have a much higher number of worker bees than wild hives, the usurping queens were likely being swarmed by the smaller bees and overpowered. The finding reveals another previously unknown way that humans are impacting wild bee populations, which are generally in decline. This queen bee slaughter could also be reducing the pollination benefits of commercial beekeeping because it wipes out wild queens.

**Did you know?**
There are around 250 species of bumblebees

In the new study, researchers tested out a new device that physically blocks wild queens from entering commercial hives, while still allowing workers to come and go as they please. The queen excluders were 100 per cent effective at keeping wild queens out without compromising the hive's efficiency. The team believes that these devices should be rolled out to commercial growers who invest in the bees to help pollinate their crops. "If you are a commercial grower and you are wanting to manage bumblebees, you may actually be reducing your overall pollination services by investing in these commercial bumblebee colonies, unless you are taking some risk-mitigation strategies like putting in a queen excluder," said Heather Grabb, an agricultural scientist at Cornell University.

A series of images from the study, including CT scans that 'digitally unwrapped' the mummy

HISTORY

# Scans of the 'golden boy' mummy reveal 49 hidden amulets

WORDS JENNIFER NALEWICKI

Incredibly detailed computed tomography (CT) scans of the 'golden boy' mummy from ancient Egypt have revealed a hidden trove of 49 amulets, many of which are made of gold. The young mummy earned its nickname because of the dazzling display of wealth, which included a gilded head mask found in the mummy's sarcophagus. Researchers think he was about 14 or 15 years old when he died because his wisdom teeth had not yet emerged. The golden boy was originally unearthed in 1916 at a cemetery in southern Egypt and has been stored in the basement of The Egyptian Museum in Cairo ever since. The mummy had been in an outer coffin with a Greek inscription and an inner sarcophagus.

While analysing the scans, researchers found that the amulets, comprising 21 different shapes and sizes, were strategically placed on or inside his body. "This mummy is a showcase of Egyptian beliefs about death and the afterlife during the Ptolemaic period," said Sahar Saleem, a professor of radiology at Cairo University in Egypt. While researchers aren't sure of the mummy's true identity, based on the grave goods alone they think he was of high socioeconomic status.

The amulets served important roles in the afterlife. "Ancient Egyptians believed in the power of amulets... and they were used for protection and for providing specific benefits for the living and the dead," Saleem said. "In modern science, this is explained by energy. Different materials, shapes and colours provide energy with different wavelengths that could have [an] effect on the body. Amulets were used by ancient Egyptians in their lives. Embalmers placed amulets during mummification to vitalise the dead body." For example, the teenage mummy's tongue was capped in gold "to enable the deceased to speak", and the sandals "were to enable the deceased to walk out of the tomb in the [afterlife]."

However, one amulet in particular stood out to Saleem: the golden heart scarab placed inside the torso cavity. She wound up creating a replica of it using a 3D printer. "It was really amazing, especially after I 3D printed [it] and was able to hold it in my hands," Saleem said. "There were engraved marks on the back that could represent the inscriptions and spells the priests wrote to protect the boy during his journey. Scarabs symbolise rebirth in ancient Egypt, and [were] in the form of a discoid (disc-shaped) beetle."

She added that the heart scarab measured about four centimetres and was inscribed with verses from the Book of the Dead, an important ancient Egyptian text that helped guide the deceased in the afterlife. "It was very important in the afterlife when judging the deceased and weighing the heart against the feather of Maat [the goddess of truth]," Saleem said. "The heart scarab silenced the heart [on] judgement day so not to bear witness against the deceased. A heart scarab was placed inside the torso cavity during mummification to substitute for the heart if the body was ever deprived [of] this important organ for any reason."

© Alamy / NASA; JPL-Caltech; UArizona

Alexander the Great, pictured here in a mosaic on a palace wall in Pompeii

HISTORY

# AI is deciphering a 2,000-year-old text

WORDS **OWEN JARUS**

A 2,000-year-old 'lost book' discussing the dynasties that succeeded Alexander the Great may finally be deciphered nearly two millennia after the text was partially destroyed in the eruption of Mount Vesuvius in 79 CE and centuries later handed off to Napoleon Bonaparte. The reason for the breakthrough? Researchers are using machine learning – a branch of artificial intelligence – to discern the faint ink on the rolled-up papyrus scroll. "It's probably a lost work," said Richard Janko, the Gerald F. Else distinguished university professor of classical studies at the University of Michigan. The research is not yet published in a peer-reviewed journal.

Only small parts of the heavily damaged text can be read right now. "It contains the names of a number of Macedonian dynasts and generals of Alexander," Janko said, noting that it also includes "several mentions of Alexander himself." After Alexander the Great died in 323 BCE, his empire fell apart. The text mentions the Macedonian generals Seleucus I Nicator, who came to rule a large amount of territory in the Middle East, and Cassander, who ruled Greece after Alexander's death.

The lost book is from the Villa of the Papyri at Herculaneum, a city that was destroyed alongside Pompeii when Mount Vesuvius erupted after the turn of the first millennium. The villa, named for its vast scrolls of papyri, contains numerous writings from the philosopher Philodemus, who lived circa 110 to 30 BCE. These papyri were carbonised when the volcano erupted. At some point the text was discovered, and it was given to Napoleon Bonaparte in 1804. He gave it to the Institut de France in Paris, where it now resides. In 1986, an attempt to unroll the papyrus resulted in further damage.

Janko has been studying the papyrus with help from a team led by Brent Seales, director of the Center for Visualization and Virtual Environments at the University of Kentucky. To uncover the papyrus' secrets, Seales' team has been using machine learning: they've trained a computer program how to detect ink on papyri by letting it analyse ancient scrolls with computed tomography (CT) scans, which take thousands of X-rays to make three-dimensional digital images. "They have visible writing, so we can match up the ink locations with the exact place to search for that ink in the micro-CT," said Seales.

**Did you know?**
Alexander likely died from malaria or typhoid fever

During a presentation, Janko noted that Seales' team's work is gradually making more of the text on the papyrus legible. "With each iteration of his work, the ability to read more of these fragments is getting better every time," Janko said.

However, much about the scroll remains a mystery. The author of the text is unknown. It's also unclear why it was inside the villa at Pompeii. Janko noted that many of the texts in the villa were written by Philodemus and discuss philosophy, not history. Janko suggested that the text may have been borrowed and not returned.

HEALTH

# Fatal 'brain-eating' amoeba successfully treated

WORDS **NICOLETTA LANESE**

A drug for urinary tract infections may also work for 'brain-eating' amoeba infections, fatal for the vast majority of people who contract them. The drug's promise was demonstrated in a recent case report that describes a 54-year-old man whose brain was infiltrated by the amoeba *Balamuthia mandrillaris*. The single-celled organism lives in dust, soil and water and can enter the body through skin wounds and cuts or through the lungs when it's inhaled.

The amoeba can then enter the bloodstream and travel to the brain, triggering a very rare infection called granulomatous amebic encephalitis that kills around 90 per cent of those affected. "The disease might appear mild at first, but can become more severe," according to the Centers for Disease Control and Prevention (CDC).

The man in the case report initially received treatment at a Northern California hospital for an unexplained seizure. Magnetic resonance imaging (MRI) revealed a mass on the left side of his brain, surrounded by swelling. At this point, the man was transferred to the University of California, San Francisco (UCSF) Medical Center, where doctors took samples of the patient's brain tissue and the clear fluid surrounding the brain and spinal cord. This analysis revealed *B. mandrillaris* in the man's brain. After consulting the CDC, the patient's doctors prescribed an aggressive regimen of antiparasitic, antibacterial and antifungal drugs. "It's what's recommended because it was what happened to be used in patients who survived," said Dr Natasha Spottiswoode, an infectious disease physician-scientist at UCSF. Unfortunately, the treatment triggered severe side effects, including kidney failure, and the patient wasn't yet amoeba-free.

In search of another solution, Spottiswoode dug up a 2018 report in which UCSF scientists found evidence that an antibiotic called nitroxoline can kill *B. mandrillaris* in laboratory settings. The drug is approved in Europe, but not the US, so the medical team sought permission from the Food and Drug Administration to use it. They got approval, started the patient on nitroxoline and observed rapid improvement within a week. The patient was soon discharged from the hospital and continued to take nitroxoline at home, along with other medications; his clinicians plan to eventually discontinue his use of the drugs. In the meantime, UCSF doctors are overseeing the case of a second *B. mandrillaris*-infected patient who's started receiving nitroxoline. They are seeing similar improvements.

This organism can trigger a very rare brain infection called granulomatous amebic encephalitis, which is fatal for most of those infected

The ESA's Jupiter Icy Moons Explorer (JUICE) spacecraft being unpacked at Europe's Spaceport in French Guiana

SPACE

## EUROPE'S JUPITER EXPLORER ARRIVES AT THE SPACEPORT

WORDS **ANDREW JONES**

**The European Space Agency's (ESA) Jupiter Icy Moons Explorer (JUICE) has arrived at Europe's Spaceport in French Guiana for final preparations for launch. JUICE departed from Airbus facilities in Toulouse, France, on 9 February and has been unpacked at Kourou. The spacecraft will go through final checks and fuelling ahead of launch on an Ariane 5 rocket. The mission is scheduled to lift off on 13 April, when it will embark on an eight-year voyage to Jupiter to observe its icy moons Europa, Callisto and Ganymede. The spacecraft carries ten science payloads and will make 35 flybys of the moons, studying their magnetic fields and looking for clues about the conditions in their subsurface oceans and if these could potentially support life.**

**JUICE will finally enter orbit around Ganymede in 2034 for the final part of its mission and become the first spacecraft to orbit a moon other than our own. Once in space, JUICE will deploy huge solar arrays with a total area of 85 square meters, which will be needed to power the spacecraft while orbiting Jupiter at an average distance of 484 million miles from the Sun. JUICE was selected by the ESA as a flagship mission in 2012 as part of its Cosmic Vision program.**

© Alamy / Getty / ESA-CNES-Arianespace;Optique video du CSG;S. Martin

# WISH LIST

The latest tech for THE OUTDOORS

## YETI PANGA 28-LITRE WATERPROOF BACKPACK

**WWW.YETI.COM £300 / $300**

A good backpack is essential when venturing into the outdoors. The Panga backpack by YETI is one of the most robust backpacks on the market, although it comes with an equally hefty price tag. The main advantage of this bag is its waterproof design. You won't have to worry if you've left it in the rain or need to carry it over your head while you cross a lake. Thanks to a leak-proof HydroLok zipper and puncture-resistant, high-density nylon ThickSkin shell, the contents of this bag are protected from adverse wet weather conditions. The Panga has a capacity of 28 litres and is packed with internal pockets and mesh compartments to keep your valuables safe during your adventures.

## SEEKER TWO-LITRE WATER BOTTLE

**WWW.HYDRAPAK.COM FROM £18.99 / $25**

It's very important to stay hydrated while hiking over hillsides or trampling through the forest, but heavy-duty water bottles can be bulky and take up much needed space. The Seeker is an ultra-lightweight, collapsible water bottle that can keep you hydrated without taking up too much room. There are several different sizes of the Seeker bottle to choose from – from two to six litres. The body of the bottle is made from durable and tear-resistant BPA and PVC-free plastic and nylon that can be folded and crushed into the size of a fist. The Seeker can also withstand being frozen and hold hot water up to 60 degrees Celsius. Its 42-millimetre cap is compatible with threaded screw filters if you're looking to safely sample some of nature's water sources.

## PRESTO NOMAD

**WWW.GOPRESTO.COM**

**£89.39 / $105.99**

Presto's Nomad is a picnic-style slow cooker that lets you take home-cooked meals along for the ride. From soups and casseroles to chicken wings and pulled pork, the Nomad slow cooker can cook your favourite slow cooker recipes, but gives you the freedom to take them on the road. The Nomad has a capacity of around nine litres and comes with three cook settings, including high, low and keep warm. To make this slow cooker suitable for transport, its design includes a cool-touch housing unit and a lockable, spill-proof lid. The Nomad is a great gadget for transporting food for fun days out, but the device isn't necessarily suited to a campsite kitchen as it requires a mains electrical outlet for power.

# LUCI SOLAR STRING LIGHTS

**WWW.MPOWERD.COM**
**£39.95 / $54.95**

If you're spending the night in a tent beneath the stars, these string lights will bring a colourful ambience to your campsite. The Luci solar string lights feature six colours to choose from, including violet, turquoise, pink, blue, green and a cool white hue. The string lights expand to around five metres in length, so there's more than enough to illuminate your tent. To ensure that you're never without light, Luci is powered in the day using a solar panel and can last up to 15 hours on a single charge. For a quick charge, there's also the option to connect to a power source via USB. Each of the 20 LED lights and their connecting cord can be wrapped inside the device's expandable unit and hidden away for later use.

# BIGBLUE SOLARPOWA 14

**WWW.BIGBLUE-TECH.COM** **£46.99 / $39.99**

If you're planning to wander through the great outdoors but need reliable recharging for your electronic devices, packing a portable power source is a must. The BigBlue Solarpowa 14 uses a compact solar charger that takes in light energy from the Sun and turns it into battery life for your devices. Four solar panels make up the Solarpowa 14, folding together into a compact notebook size and weighing around 360 grams. The Solarpowa 14 comes with built-in recognition software that detects your device to provide safe charging. The material that houses the panels is made out of industrial-strength and waterproof PET polymer fabric that's more than suitable for your outdoor adventures. Simply clip the panels to your backpack while you walk around and your devices will have access to extra juice when you arrive at your destination.

# JBL XTREME 3

**WWW.JBL.COM** **£249.99 / $279.95**

Bring music to the outdoors with this robust portable speaker from JBL. The Xtreme 3 is a Bluetooth speaker that delivers powerful sound while you're outside. Waterproof and dustproof, the Xtreme 3 is a great addition to a beach break or a lakeside camp. Using the speaker's PartBoost feature, you can pair multiple JBL Party Boost-capable speakers to create surround sound. This speaker can also connect to two smartphones or tablets at the same time for better music sharing. Along with being a speaker, the Xtreme 3 doubles as a power bank with which you can charge your electronic devices, and comes included with a carry strap. With a maximum battery play time of 15 hours of music, you can enjoy your favourite tunes all day long.

© JBL / BigBlue / Yeti / Mpowerd / Hydrapak / National Presto Industries

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SPECIAL

**DID YOU KNOW?** There are around 800 lymph nodes in the average adult body

# YOUR IMMUNE SYSTEM EXPLAINED

WORDS SCOTT DUTFIELD

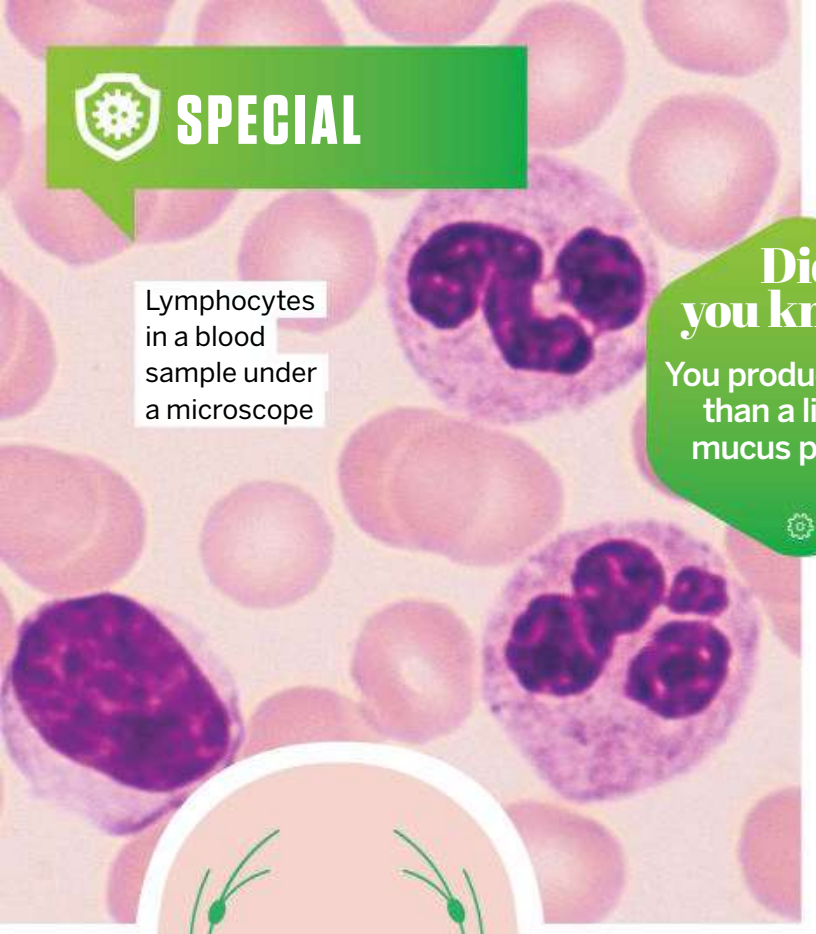
**Meet the cells and organs that make up your immune system. Discover how it keeps deadly invaders at bay and what happens when it gets out of control**

Every day your immune system is working tirelessly to fend off harmful invading pathogens such as bacteria and viruses. Our understanding of the immune system began in the late-19th century when Russian zoologist Élie Metchnikoff identified a group of white blood cells called phagocytes, whose purpose is to seek out, engulf and eliminate pathogens. During the same period, the discovery of antibodies and their role in neutralising pathogens also came to light thanks to German physiologists Emil Behring and Paul Ehrlich. Since then, scientists from around the world have come to understand the complexity of our immune system and the many ways it has evolved to fight off bacterial baddies and villainous viruses.

Part of our immune system is passed on to us as newborns from our mothers through the placenta during our time spent in the womb, and again through feeding on breast milk.

©Getty

SPECIAL



Lymphocytes in a blood sample under a microscope

**Did you know?**

You produce more than a litre of mucus per day

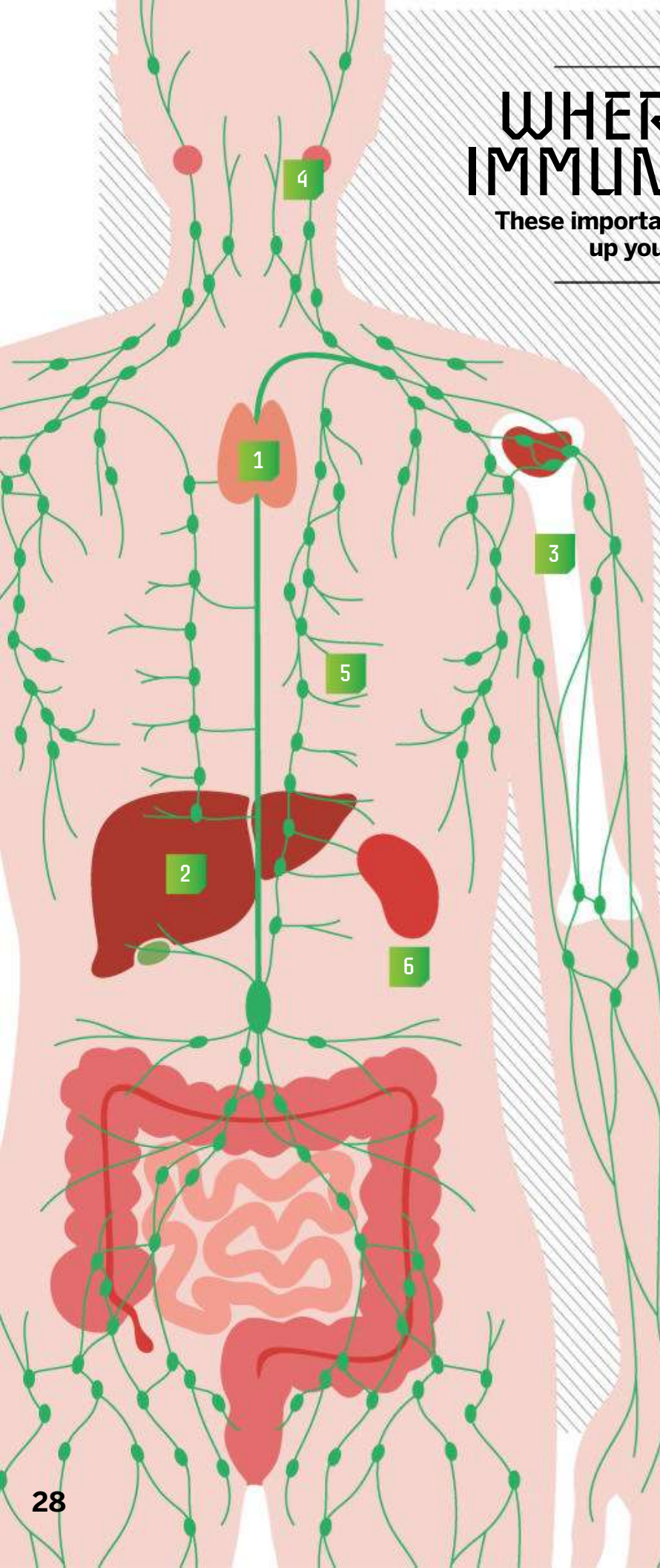
Immunity to particular viruses and bacteria and the potency of this passive immunity differs from mother to mother. For example, mothers who have had chickenpox during their lifetime can pass on that immunity to their newborn. However, this form of passive protection is short-lived and begins to decrease after the first few months of life. Over time, the immune system acquires more complex immunities after reacting with pathogens from the outside world.

Your immune response is divided into systems. The first frontline defence your body has is known as the innate immune system. The skin is our first defence against pathogens and offers a physical barrier around the body. Then there's mucus. Snot acts like quicksand for pathogens, which become stuck in its grasp and are prevented from making it any further into the body. For those sneaky pathogens that make it past these first two lines of defence, they might find their way into the stomach, which is filled with acid that kills them off. Also, the digestive system is home to healthy bacteria that compete with invading bacteria for space and food, sometimes leading to the demise of the invading bacteria.

If a pathogen makes it past these physical barriers, then a secondary internal defence is called upon. In the event that a physical barrier, such as the skin, has been broken and there's a potential threat of invasion from outside pathogens, white blood cells called mast cells, which are found in the connective tissue near

# WHERE IS YOUR IMMUNE SYSTEM?

**These important parts of the body make up your immune system**




**1 THYMUS**
White blood cells called lymphocytes arrive at the thymus from the bone marrow and mature into T cells.

**2 LIVER**
White blood cells called phagocytes are stored here. The liver can also detect when pathogens enter the body.

**3 BONE MARROW**
This is the factory for all immune cells, which begin as immature stem cells and diversify into specialised immunity cells.

**4 TONSILS**
A collection of lymphocytes can be found in the tonsils. These cells are one primary defence against pathogens.

**5 LYMPH NODES**
Immunity cells called B cells and T cells gather in the lymph nodes to communicate with each other.

**6 SPLEEN**
This filters out pathogens such as bacteria and viruses from the blood, and also detects faulty blood cells.

## HERD IMMUNITY

**During the height of the coronavirus pandemic, you might have heard the term 'herd immunity' being used. This form of immunity occurs when the majority of a population, or 'the herd', is immune to a particular infectious disease. At the point at which the herd is predominantly immune, the disease is less likely to spread. For example, if a person infected with highly contagious measles were to stand in the centre of a group of vaccinated people, the disease would be unable to be transmitted and would eventually disappear. This type of immunity also helps those that are unable to be vaccinated, such as newborns and the elderly.**

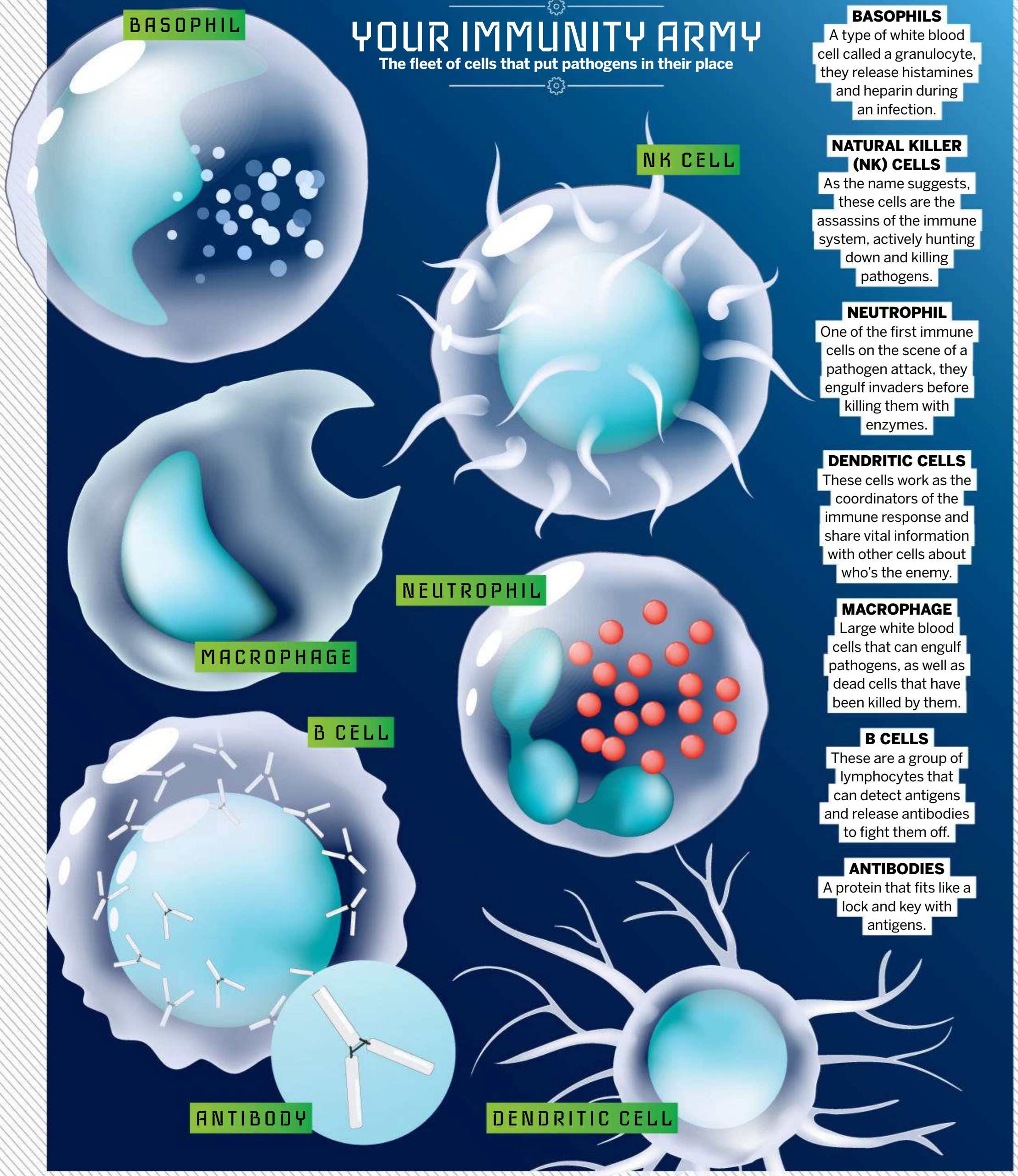
**For herd immunity to be effective, the people vaccinated or immune to the disease need to outnumber the rate at which the disease can spread. Measles, for example, can spread at such a rapid rate that 19 out of 20 people need to be vaccinated for herd immunity to be achieved.**

For herd immunity to work, the majority of the population needs to be vaccinated

**DID YOU KNOW?** Macrophages can digest more than 100 bacteria before they die

# YOUR IMMUNITY ARMY

**The fleet of cells that put pathogens in their place**




**BASOPHILS**
A type of white blood cell called a granulocyte, they release histamines and heparin during an infection.

**NATURAL KILLER (NK) CELLS**
As the name suggests, these cells are the assassins of the immune system, actively hunting down and killing pathogens.

**NEUTROPHIL**
One of the first immune cells on the scene of a pathogen attack, they engulf invaders before killing them with enzymes.

**DENDRITIC CELLS**
These cells work as the coordinators of the immune response and share vital information with other cells about who's the enemy.

**MACROPHAGE**
Large white blood cells that can engulf pathogens, as well as dead cells that have been killed by them.

**B CELLS**
These are a group of lymphocytes that can detect antigens and release antibodies to fight them off.

**ANTIBODIES**
A protein that fits like a lock and key with antigens.

©Getty

# FIGHTING INFECTIONS

**How your immune system actively responds to a pathogen invasion**

**Did you know?**

Neutrophils make up around 70 per cent of your white blood cells

**PATHOGEN**

**1 B CELL**
These are covered with antibodies. When they come into contact with an antigen in the blood or the spleen, they immediately bind to it.

**4 MEMORY CELLS**
Some B cells stay away from the fighting to preserve their antibodies in case of a future attack.

**5**

**7 CALL IN THE BIG GUNS**
Antibodies have more than one binding and can partly bind with multiple pathogens, acting like glue to clump them together in a process known as agglutination.

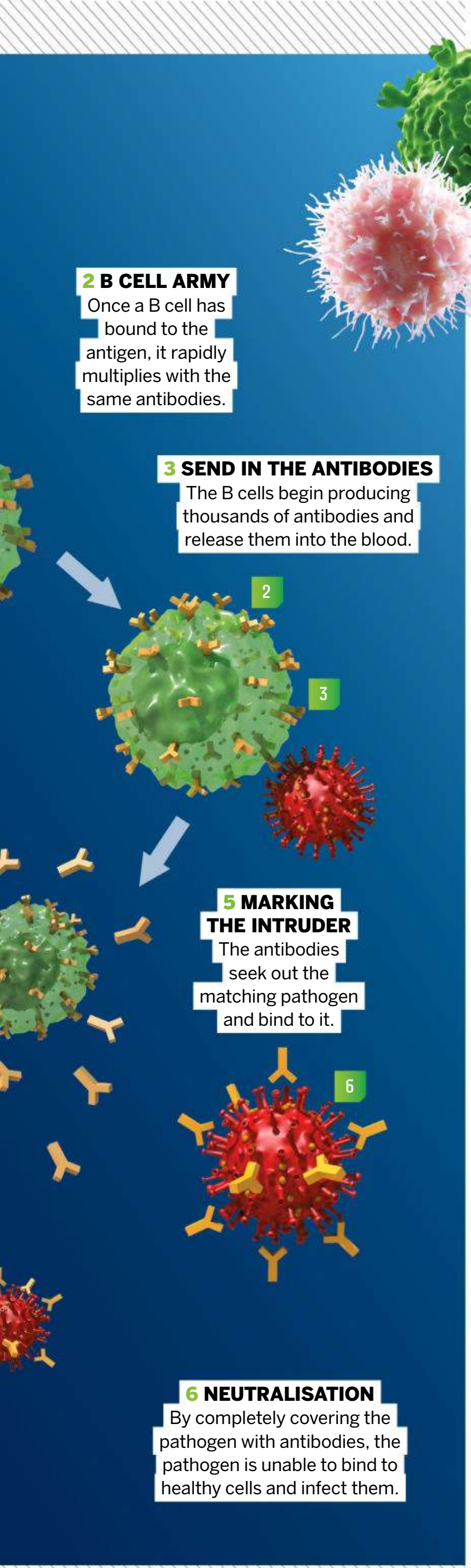
**8 MEALTIME**
Macrophages are capable of recognising and completely engulfing either clumped-up pathogens or dead infected cells through a process called phagocytosis.

**9 SHOW AND TELL**
When a phagocyte engulfs a pathogen, it presents parts of the pathogen on its surface, called a major histocompatibility complex (MHC).

**10 ASSASSINS**
T helper cells detect the MHC presented on the phagocyte's surface and release signalling proteins called cytokines to activate NK cells to destroy infected cells.

**11 INFECT THE INFECTED**
Once an NK cell has spotted an infected cell, it binds with it and releases enzymes into the cell to kill it, along with the pathogen within.

**DID YOU KNOW?** If all the viruses on Earth were placed end to end, they would span 100 million light years

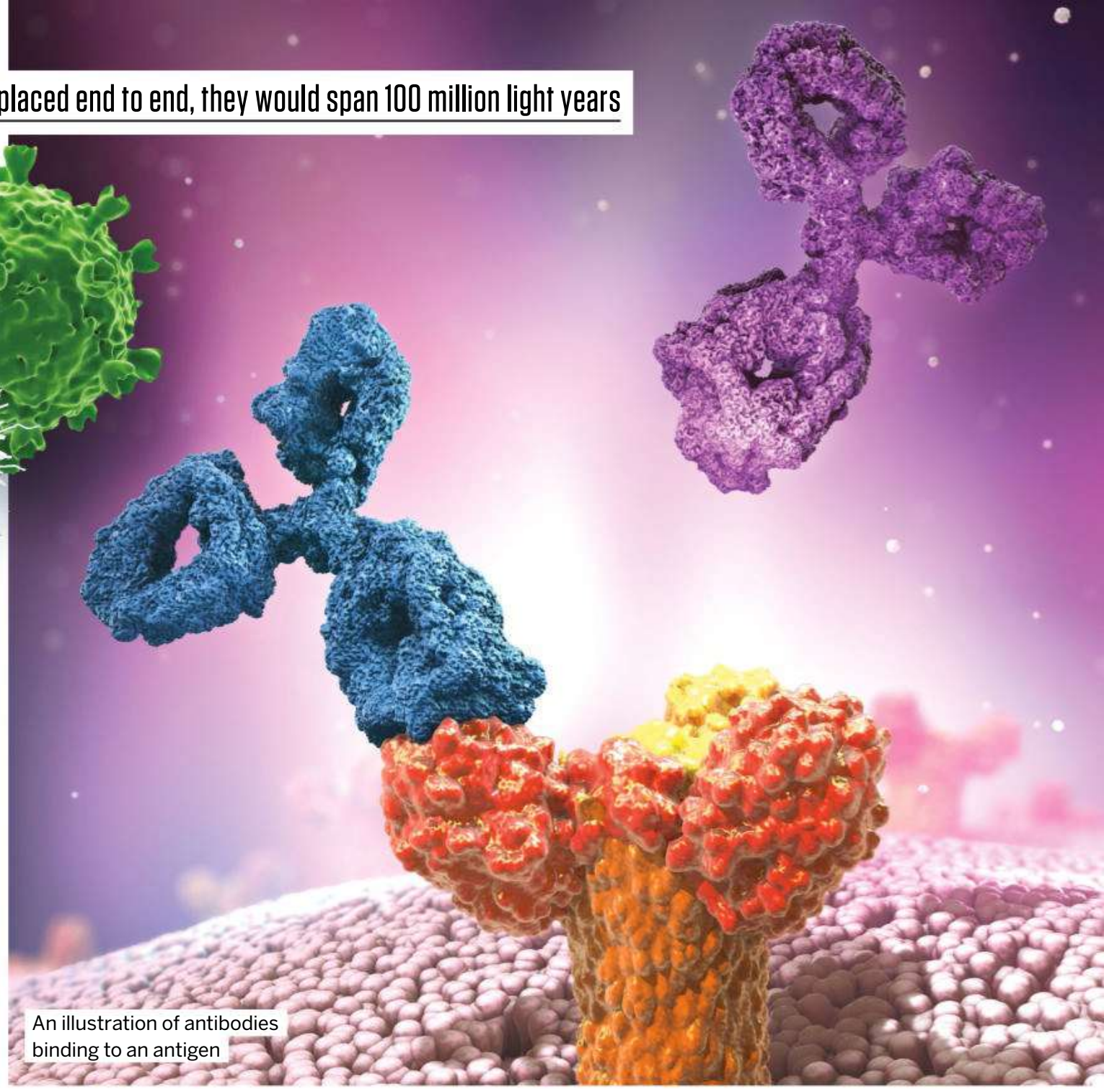



**2 B CELL ARMY**
Once a B cell has bound to the antigen, it rapidly multiplies with the same antibodies.

**3 SEND IN THE ANTIBODIES**
The B cells begin producing thousands of antibodies and release them into the blood.

**5 MARKING THE INTRUDER**
The antibodies seek out the matching pathogen and bind to it.

**6 NEUTRALISATION**
By completely covering the pathogen with antibodies, the pathogen is unable to bind to healthy cells and infect them.



An illustration of antibodies binding to an antigen

blood vessels, release histamine into the blood to initiate the body's inflammatory response.

The first soldiers to battle pathogens are a group of white blood cells called phagocytes. The most abundant phagocytes in the human body are called neutrophils, which gobble up pathogens on sight. Once a pathogen is devoured, the neutrophil essentially self-destructs in a process called apoptosis, killing the pathogen in the process. During infection, the bodies of self-destructed neutrophils pile up and form pus at the site of a wound.

Outside of the bloodstream, larger phagocytes called macrophages also engulf pathogens, but can be found free-flowing through tissue or embedded into tissues such as the lymph nodes or intestinal tract. If the war against pathogens isn't going in the phagocytes' favour, they can release chemicals into the blood called pyrogens to trigger a fever. Once the pyrogens reach the brain's hypothalamus, they cause it to raise the body's temperature, giving your immune cells a metabolic boost for battle but inducing stress in pathogens.

In the event that these innate defences can't completely fend off pathogens, the second division of the immune system, known as adaptive or active immunity, kicks into gear. In this system, a legion of white blood cells called lymphocytes work together to seek out and destroy pathogens that enter the bloodstream. The key elements in the active immune system are antigens and antibodies. Antigens are like the identification cards for pathogens and antibodies are like pathogen mugshots. When the two are compared and a positive match is found, immune cells are altered and the elimination process begins.

Sometimes the volume of invading bacteria can overwhelm the body's immune system and it can't produce enough immune cells to fight off a serious infection, such as pneumonia. In this case, the immune system may need a helping hand from medication, called antibiotics, to eradicate bacterial pathogens. Antiviral medication also works to limit the infectious abilities of some invading viruses, giving the immune system a chance to defeat them.

**Did you know?**
70 per cent of immunity happens in the digestive tract

Similarly, vaccines are used to stimulate our natural immune response against specific pathogen threats. Vaccines work by releasing proteins called antigens into the body, which the immune system recognises as foreign and a potential pathogen. The antigen in the vaccine will have the same proteins as that of the pathogen you're vaccinating against, such as measles. This sets the active immune system into motion, creating antibodies to fight a potential infection. The immune system will store or 'remember' the antibodies it needs in case of a future infection.

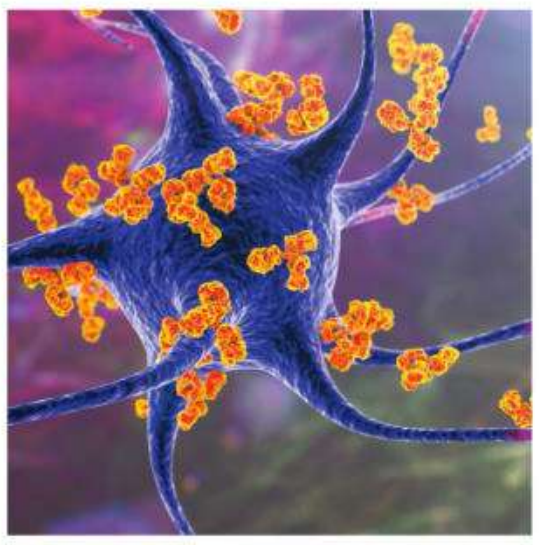
© Getty / Illustration by Adrian Mann

# WHEN THE IMMUNE SYSTEM TURNS ON ITSELF

Sometimes the human immune system misinterprets healthy tissue as invading pathogens and sets out to remove it. In a typical immune response, T cells release cytokines that instruct other immune cells when and where to attack and when to fall back. But sometimes this cellular communication goes wrong and the immune cells can't correctly identify what's a pathogen and what's healthy tissue, which leads to the development of autoimmune diseases such as lupus and rheumatoid arthritis.

There are more than 100 known autoimmune diseases, some more serious than others. Multiple sclerosis, for example, is a chronic disease of the central nervous system caused by an autoimmune response. Instead of solely fighting invading pathogens, immune cells attach to nerve cells and prevent them from sending electrical signals to and from the brain. It's still unclear why autoimmune diseases develop and what causes the immune system to stop recognising healthy tissue. However, scientists have made some connections between autoimmune diseases and possible triggers, such as an immune response to an infection like strep throat that can lead to the development of an autoimmune disease like psoriasis.

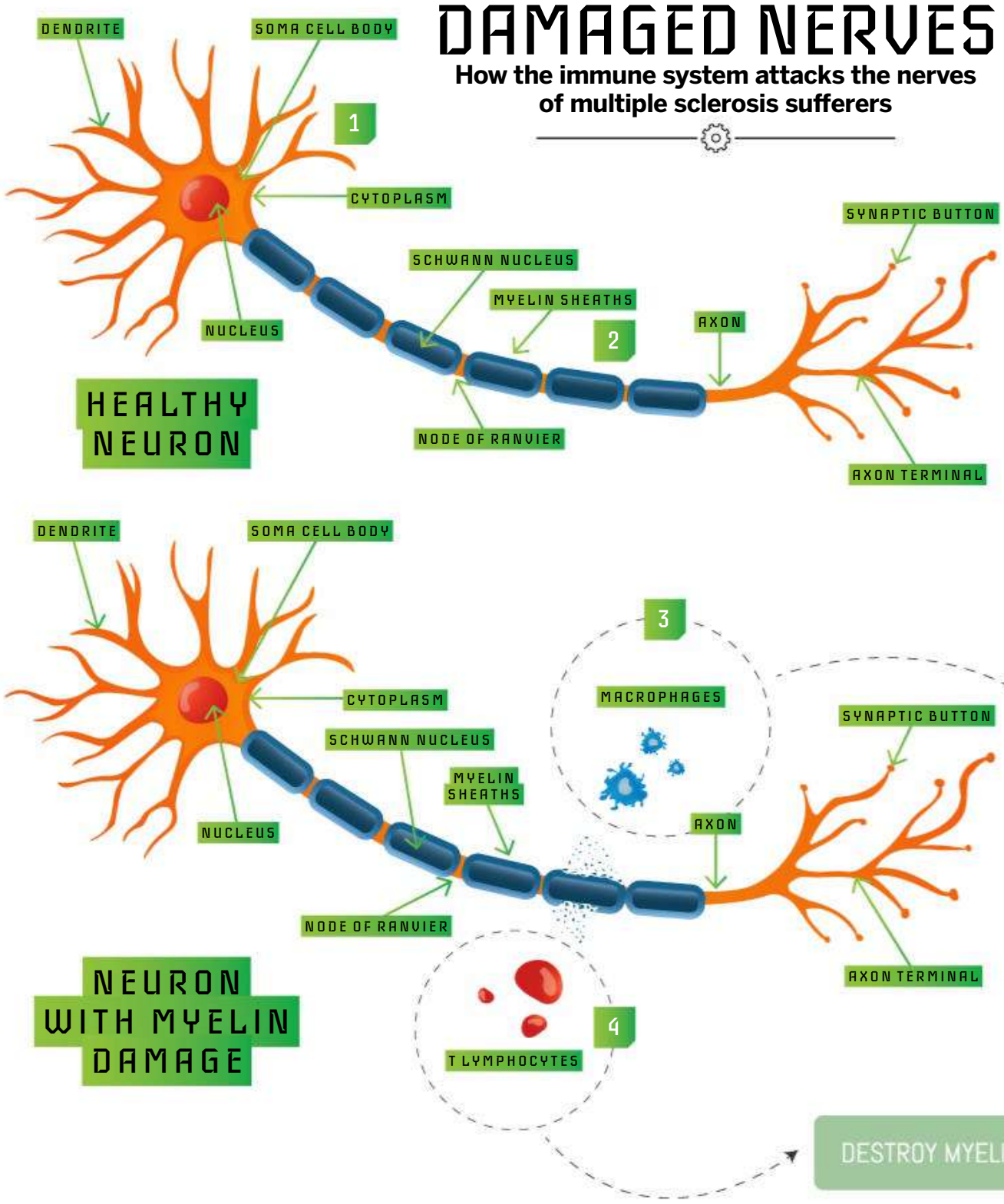
Injury or damage to a part of the body may also trigger the development of a disease such as psoriatic arthritis, which affects the joints. Along with some environmental factors, genetics may also play a pivotal role in the development of some autoimmune diseases.



An illustration of immune cells attacking a healthy nerve cell

# DAMAGED NERVES

**How the immune system attacks the nerves of multiple sclerosis sufferers**




**1 HEALTHY NEURON**
These are specialised cells that send information around the nervous system through electrical signals.

**2 MYELIN**
This fatty membrane wraps around the nerve for protection and allows electrical signals to pass along the cell.

**3 DESTROY MESSAGE**
T cells send the alarm to macrophages to seek and destroy the neuron's myelin.

**4 INFLAMMATION**
Macrophages and other lymphocytes damage the myelin and create inflammation along the nerve.

Both psoriasis (above) and lupus (right) are autoimmune diseases that most noticeably affect the skin

**Did you know?**

10 million Americans have an autoimmune disease

**DID YOU KNOW?** The thymus shrinks at a rate of three per cent per year until middle age

# IMMUNITY MYTHS

Sheena Cruickshank, an immunologist and a professor of biomedical sciences and public engagement at the university of Manchester, separates immunity facts from fiction

**Does stress lower your immune response?**
Chronic stress does, so the longer you're stressed, it absolutely does. I think a short, sharp stress isn't damaging for your immune system. Some people suggest it might give you a little transient boost. But chronic stress, if you stress for a long period of time, does impede the actions of immune cells.

**Does immunity weaken with age?**
Yes, unfortunately it does. As we get older, the majority of us will see a decline in our immune function. We may have fewer of the specialised white blood cells called lymphocytes that are there to deal with infection. However, it's not always as severe in some older people; some older people do age well. And one thing that might be linked to that is having a good, diverse microbiome. It helps maintain the barrier in your gut, and that stops you getting kind of a leaky gut and getting this low-level inflammation that can happen when you're older, and that can further make your immune system a bit off.

**Does vitamin C boost the immune system?**
The evidence for that is rather mixed. A healthy diet is important for an optimal immune system. But studies on vitamin C have been really mixed. There's not a really clear link with vitamin C per se. The exception is vitamin D. A lot of people can be vitamin D deficient, particularly in the winter months when we get less sunlight. And you have to eat quite a lot of particular food types to really try and enrich that in your diet. And people who have low vitamin D do seem to be a bit more susceptible to catching colds.

**Is the idea of being able to boost your immune system a myth?**
There is one way that you can truly boost your immune system, and that's having a vaccine. I mean, that's what a vaccine is doing – it's boosting your immunity to stop you getting sick in response to a particular infection. But the idea that we can boost our general immunity is a myth. For most of us, our immune system is doing a pretty good job. I mean, we're exposed to infections and nasty germs every day, and most of the time we don't get ill.

**Does sleep have any impact on our immune system?**
It's important to have sleep for our immune systems, like all sorts of cells in our body. Pretty much all the cells in the body have little circadian clocks and they help kind of optimise our function, so lack of sleep can throw those out, and it can definitely affect your immune response. And we know it ourselves. If we've been going through a phase or we've not been sleeping well and we've been stressed or we've not been eating well, then we do often get run down; we'll often get that horrible infection taking hold.

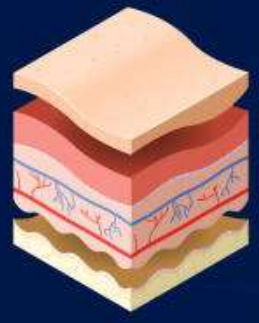
**Does exercise lower your immune system?**
Now, it all depends how you exercise. Moderate exercise is a benefit for your immune system, so moderate levels of activity, that's kind of what the NHS is recommending. Three or four bursts of moderate kinds of exercise where you can really feel your heart starting to get going. The 10,000 steps a day was thought to be a bit of a kind of random figure, but actually it's been assessed since, and that does look like a good thing to aim for. So all of these things seem to be good at mobilising your immune system, helping it operate better, detect infection, deal with infections better, and you seem to have a lower risk of upper respiratory tract infections, like colds. But if you do extreme sports and you're absolutely not used to it, that puts your body under stress and that is not so good for your immune system. It's that balance, and also how acclimatised you are too.

**What's a common myth you often debunk?**
One of the things that really worries me that I'm seeing a lot more of at the moment is this idea that it's good for children to get infected and build their immune system. I don't really understand where that narrative has come from. Actually, we know that children under the age of five are some of the most vulnerable to infection.

© Getty / Alamy / University of Manchester

SPECIAL

# YOUR IMMUNE SYSTEM BY NUMBERS



## 0.5 TO 4.0 MILLIMETRES

**Our skin's physical barrier to the outside world fluctuates in thickness around the body**

## 1 QUINTILLION

**The number of unique antibodies the human body can make**

**Obese adults with the influenza A virus are contagious for**

## 42%

**longer than non-obese adults**

## 1,400

**The number of known species of human pathogens**

## 4.5 METRES PER SECOND

**You sneeze with around the same velocity as a fast jogging pace**

## 4 million

**Childhood vaccines prevent millions of unnecessary deaths in the US each year**

## 70 to 75%

**Of the five types of antibodies, immunoglobulin G (IgG) is the most abundant**

## 1796

**The first vaccine, created by Dr Edward Jenner, was used to combat smallpox**

## There are up to 11,000,000 white blood cells per millilitre of blood

**DID YOU KNOW?** Type 1 diabetes is thought to be caused by an autoimmune reaction

# Phagocyte comes from the Greek word phago, meaning ‘to eat or devour’, and cyte for ‘cell’

## ♀78%

Over three-quarters of people with autoimmune diseases are women

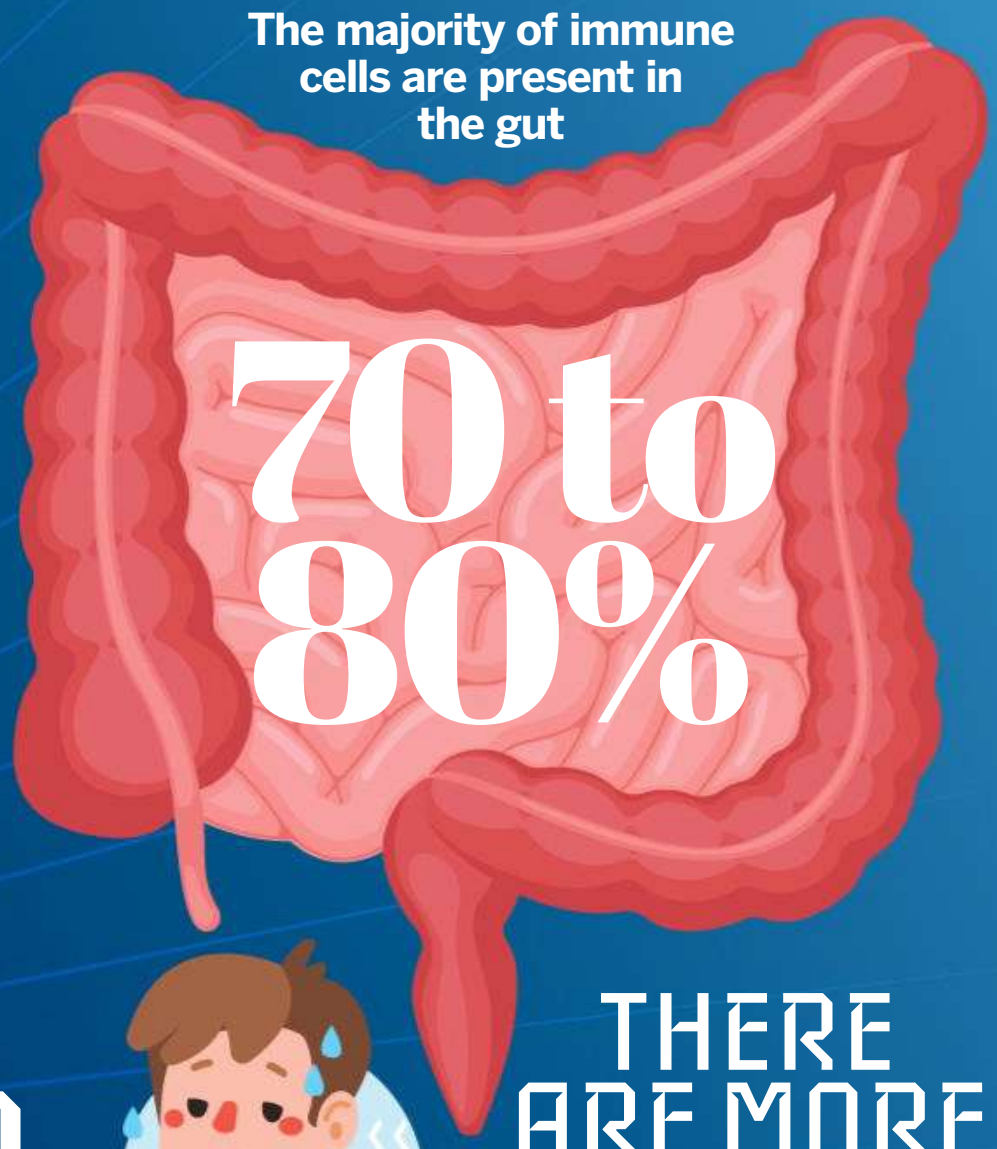
## 1%

White blood cells make up a fraction of the total cells in your blood

## ONE IN 100,000

Severe combined immunodeficiency, or ‘bubble boy disease’, is very rare

The majority of immune cells are present in the gut



## 70 to 80%

## THREE WEEKS

It can take a while for the immune system to recognise a pathogen that can make you ill

## THE HUMAN IMMUNE SYSTEM IS STRONGEST BETWEEN THE AGES OF 10 TO 50 YEARS OLD

## 37.8 DEGREES CELSIUS

A fever occurs at 0.8 degrees Celsius higher than normal body temperature

## THERE ARE MORE THAN 200 VIRUSES THAT CAUSE THE COMMON COLD

## 10:1

Trillions of bacteria found in humans outnumber our own body’s cells

## 430 BCE

The earliest reference to immunity dates date to the ancient Greeks

## 500 MILLION YEARS AGO

The active immune system evolved long before land animals appeared

© Getty

# SPACESUIT SCIENCE

## How spacesuit technology has protected astronauts for decades

WORDS **AILSA HARVEY**

Humans evolved to perfectly suit the conditions on Earth. To venture out of the atmosphere, we need to artificially create these conditions. With durable and reliable materials and the most up-to-date technology and engineering, spacesuits surround the body with a bubble of air at the same pressure as that felt on our planet. Oxygen is stored and pumped to the head for breathing in environments that an exposed body would suffocate in.

The person recognised for inventing the concept of the spacesuit is Spanish scientist Emilio Herrera, who dreamed of reaching the stratosphere, though his missions were in the form of a hot-air balloon ride into a less hostile environment than today's space missions, Herrera created a suit that provided him oxygen and protected his body from cold temperatures and pressure changes. This was the first version of the spacesuit, which achieves control of the same three elements. His invention is what inspired NASA's first spacesuit, developed around 30 years later.

There are a range of successful spacesuits that are worn at various stages of a mission – from the intravehicular activity (IVA) type, designed just for the journey to and from space, to the robust extravehicular activity (EVA) suits that need to remain unfaltering when exposed to extreme temperatures, pressures and other unpredictable spacewalking hazards.

Herrera's initial vision is still in place, but the limits of this vision have been pushed further. The next challenge for spacesuit designers to tackle involves spacesuits that allow astronauts to set foot on other planets and for longer-term space excursions.

**DID YOU KNOW?** Spacesuits protect the body from extreme temperatures between 120 and -156 degrees Celsius

# LAYER BY LAYER

**How they support an astronaut's life**

**1 VISOR**
A thin layer of gold covers the spacesuit visor. This protects the astronaut's eyes from the Sun's harmful ultraviolet radiation.

**2 PRIMARY TANKS**
In space, astronauts breathe 100 per cent oxygen instead of the 20 per cent they would breathe on Earth. This removes nitrogen from the body, which can form life-threatening bubbles when exposed to space's low pressures.

**3 SECONDARY TANKS**
Oxygen is circulated around the entire suit to keep the air pressure constant.

**4 HARD UPPER TORSO**
The central body is made from fibreglass. Modules such as the life-support pack attach to the torso.

**5 COOLING UNDERGARMENT**
Thin tubes are pumped with cool water that circulates this spandex undersuit to control an astronaut's temperature.

**6 BACKPACK LIFE-SUPPORT SYSTEM**
As well as housing oxygen tanks, this pack contains a radio and systems for removing carbon dioxide from an astronaut's breath.

**7 DISPLAY AND CONTROLS**
This module at the front of the suit allows the astronaut to control the life-support pack. It also displays the pressure and oxygen levels.

**8 HELMET**
Breathable oxygen is delivered from the oxygen tanks into the helmet. This strong plastic shell protects the wearer against micrometeoroids, as well as ultraviolet and infrared radiation.

**9 ELECTRICAL HARNESS**
Wires inside the suit measure vital signs and connect communication devices.

**10 THERMAL MICROMETEOROID GARMENT**
13 layers of material make up the outer part of the spacesuit, including kevlar – the material found in bulletproof vests.

**11 PHASE VI GLOVES**
Gloves are fitted with heaters, as this is usually the first part of the body to be affected by the cold.

**Did you know?**
You could survive for 15 seconds in space with no suit

## THE FIRST IN SPACE

**Yuri Gagarin was the first person to wear a suit in space in 1961. Called the SK-1, this spacesuit was centred around flexibility. To assist astronauts in their experiments, the suits incorporated materials such as latex in the undergarments, increasing the wearer's range of movement. Christian Dior was the fashion designer who led this element of the suit. The spacesuit was bright orange for visibility purposes in the case of an emergency, but was not designed for spacewalks. Instead the suit was for wearing inside a spacecraft, and could keep Gagarin alive for five hours if the cabin's air supply was lost. Another role of the bright-orange outer casing was to conceal the details of Gagarin's suit from other designers. As the spacesuit was created during the Space Race, the details of the Soviet Union's invention were hidden from other nations.**



Yuri Gagarin went to space on 12 April 1961

© Alamy / Getty

# SUITING UP

From early attire to today's technology, how have spacesuits improved?

### Mercury 1961

The main feature of these American suits was that they could be fully pressurised if the spacecraft faced pressure loss, but this never occurred.

### Berkut 1965

The Berkut suit was used for the first spacewalk, requiring a life-support system, but it proved too bulky and was used just once.

### Gemini 1965

The neoprene-coated nylon, used in layers for maintaining air pressure, gave this suit added flexibility. The Gemini had four different variations.

### Apollo A7L 1968

Neil Armstrong and Buzz Aldrin wore this suit when they became the first people to step onto the Moon. It had rubberised joints for easy movement.

### Krechet-94 N/A

This was the first suit that astronauts entered through the back. It could be used for ten hours before needing to be refilled with oxygen.

### Yastreb 1969

These provided life support for up to two-and-a-half hours. It was the first Soviet design made especially for spacewalking, with a large focus on mobility.

### Sokol 1973

The Sokol was designed as an emergency spacesuit for an event of cabin depressurisation. It couldn't be used outside a craft, but was worn during launch and landing.

### Orlan 1977

The highlight of this design is that it can be entered through the back in around five minutes. It has a screen at the front that alerts the wearer to problems.

### Shuttle Ejection Escape Suit 1981

The purpose of this suit was to keep astronauts alive after being ejected from the Space Shuttle at high speeds.

### Extravehicular Mobility Unit 1983

NASA used this spacesuit to carry out spacewalks from the Space Shuttle. To tackle the challenges of long missions, the EMU has a urine collection device.

### Launch Entry Suit 1988

An IVA suit, a communications cap was fitted underneath the helmet so that wearers could communicate clearly with ground control.

### Advanced Crew Escape Suit 1994

ACES was fully pressurised. It included a full pressure helmet, ventilation system, detachable gloves and boots, and even its own life raft for emergencies.

### Exploration Extravehicular Mobility Unit 2024

The xEMU was unveiled by NASA in 2019. Arm and leg mobility is one of the biggest advancements in this suit, which will help the next moonwalkers lift objects and move on the Moon without injury.

**DID YOU KNOW?** A futuristic concept called the SmartSuit includes self-healing skin

**Did you know?**

Neil Armstrong's spacesuit was made by a bra manufacturer

# ARTEMIS ATTIRE

**Take a look at the Artemis xEMU suit that's to be worn on the next Moon mission**

**1 MOBILE TORSO**
The lower torso is now as mobile as the upper torso, enabling Artemis astronauts to bend and kneel more easily.

**2 TORCH ILLUMINATION**
Lights attached to the helmet increase visibility near the eyeline.

**3 IMAGE RELAY**
Live images of what the astronaut is experiencing are recorded by on-helmet cameras.

**4 LIFE SUPPORT**
This portable life-support subsystem is the most complex element of the suit, controlling the airflow, odours, humidity and temperature of the suit.

**5 HARD UPPER TORSO**
Advanced joint bearings mean that the shoulders have more flexibility than previous suits. Astronauts can lift their arms high and reach across their bodies.

**6 VOICE DETECTION**
Microphones inside the upper torso automatically detect and relay speech. This means astronauts don't need to wear a communication cap under their helmet.

The Z-2 prototype features futuristic light-emitting patches

## FUTURISTIC SUITS

**The Z-2 is a NASA suit that could be used for missions on Mars. The Red Planet has harsher conditions than the Moon, making the strength of these pressure-containing suits even more vital. Without an efficient spacesuit, the bodily fluids of astronauts would boil. The idea behind the Z-2 is that many elements would be 3D-printed to create a personalised fit. The almost-fluorescent lights on its surface align with many science-fiction depictions of futuristic space travel, while also serving as useful visibility tools.**

**NASA is also experimenting with augmented reality. This would present astronauts with appropriate, critical information about the mission overlaid on anything they look at. Diagrams, statistics and other information could be projected in their headsets so that the information combines with objects in their field of vision.**

# 5 SUITS THAT HAD ISSUES

**1 WET HEAD**
During a spacewalk from the International Space Station, Luca Parmitano reported: "My head is really wet and I have a feeling it's increasing." The water likely leaked from his drinking bag.

**2 COOLING CAUTION**
The cooling system in Sergey Prokopyev's Orlan spacesuit led to his spacewalk being cancelled. Luckily, the faulty pump in the suit was spotted before the mission began.

**3 PRESSURE PROBLEM**
An intended six-hour spacewalk ended after just 14 minutes when the pressure in NASA astronaut Mike Fincke's oxygen tank fell rapidly. The oxygen leak was detected quickly and the mission was safely terminated.

**4 GLOVE BREAKAGE**
NASA astronaut Rick Mastracchio spotted a hole in his left glove during an ISS spacewalk. This forms the second-outermost layer, so Mastracchio was ordered back to the space station.

**5 BAD AIR**
The carbon dioxide-removal system in Chris Cassidy's suit malfunctioned while he was replacing batteries in the ISS' solar array. The $CO_2$ level increased inside the suit, but Cassidy suffered no physical effects as a result. His $CO_2$-removing lithium-hydroxide canister was replaced.

© Alamy / NASA / Wiki: Tyrol5; CraigBoy; Stolbovsky

# HITCH A RIDE ON LAUNCHERONE

## How does Virgin Orbit's rocket launch multiple satellites into space without a launchpad?

WORDS **AILSA HARVEY**

Designed for small unmanned missions, Virgin Orbit's LauncherOne is a medium-sized rocket that can be launched from the air. The rocket is first carried into the sky by a modified aeroplane named Cosmic Girl before it detaches and begins its journey to space. While being carried by the aircraft, its engines remain off. Then, seconds after it has been dropped, its engines roar into action and continue the journey into Earth orbit.

LauncherOne was completed in 2018, and its first successful launch took place in January 2021. Because the rocket takes off from the sky, it isn't limited to launch locations with a launchpad. However, the same large-scale evacuations and safety precautions are required. One of the locations that the rocket was launched from at the beginning of 2023 was Cornwall Airport Newquay in England.




**AIR LAUNCHER**
A Virgin Atlantic Boeing 747 plane was modified to remove over 29,000 kilograms of weight, with a rocket attachment added underneath the wing.

**PAYLOAD FAIRING**
A one-metre-diameter protective casing protects the rocket's contents from extreme aerodynamic forces and high temperatures.

### LIFTOFF
**How the world's first fully liquid-fuelled rocket launches**

**SECOND STAGE**
When the first stage separates, the second stage powers the payload into orbit at up to 17,500 miles per hour.

LauncherOne fits neatly under the left wing of an adapted Boeing 747 plane

**PAYLOAD**
Virgin Orbit's LauncherOne carries small satellites called CubeSats into space. In 2021 it carried ten of these ten-centimetre cubes.

**NEWTONFOUR**
The second stage's engine can restart multiple times to ensure that the rocket reaches the correct orbit point.

**ROCKET LENGTH**
The two-stage rocket is 21 metres long.

**DID YOU KNOW?** When LauncherOne's engine starts, around 75 per cent of Earth's atmosphere is already below the rocket

Before the rocket is released, Cosmic Girl needs to reach an altitude over 10,000 metres and be facing skywards at an angle of 27 degrees. The first of two engines then runs for three minutes to carry the rocket out of Earth's atmosphere, using an autonomous flight safety system to remain pointed in the right direction. The rocket, which is propelled by liquid oxygen and liquid kerosene, is designed to carry small satellites into orbit, with a maximum total payload of 500 kilograms. Some of the applications that the service will assist include earth observation, telecommunications and climate monitoring.

Stages separate in space

**FIRST STAGE**
When the rocket is released, the first stage powers the rocket at a maximum speed of 8,000 miles per hour.

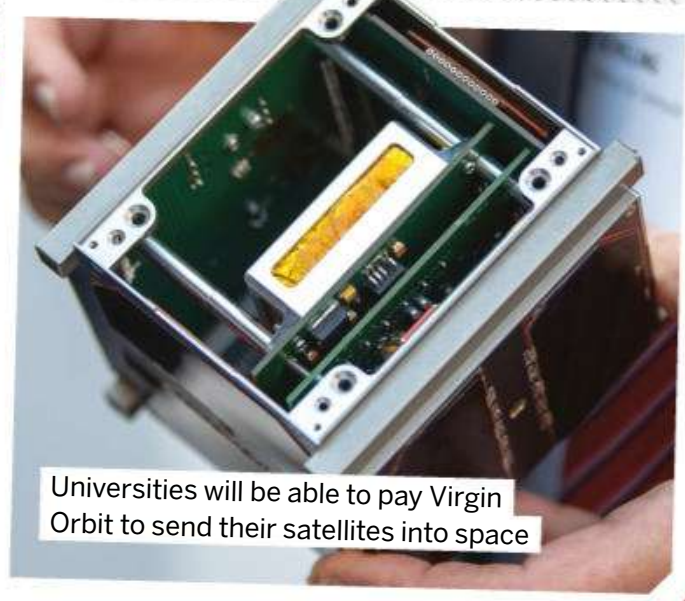
**NEWTONTHREE**
The rocket free falls for four seconds before the first stage's engine ignites.

**Did you know?**
LauncherOne weighs 25,000 kilograms

## LAUNCH FAILURE

**In January 2023, during LauncherOne's first launch from the UK and with 75,000 people watching the action live, the rocket failed to reach orbit. This was because the rocket shut down too early. The fault is believed to have been maintained solely in the rocket's second stage, since the first stage carried the rocket into space and separated from the upper stages as scheduled. Issues began when the ignition unexpectedly cut out at an altitude of 180 kilometres. This caused LauncherOne, as well as the five satellites it was carrying, to come crashing back down to Earth. After the post-launch inspection, engineers discovered the fault was due to an engine filter coming loose and being mispositioned, preventing other engine components from working properly.**

LauncherOne at Spaceport Cornwall before its failed launch



Universities will be able to pay Virgin Orbit to send their satellites into space

## SMALL SERVICE

**LauncherOne is designed to take small satellites into space. As a commercial service, Virgin Orbit's aim is to give those outside of government agencies access to space to run their own experiments. Some of the main target customers are students, and LauncherOne offers the choice of three orbital routes depending on which parts of Earth the satellites need to monitor: high, low or medium inclinations.**

**Small cubed satellites with a mass no greater than two kilograms and with dimensions of ten by ten by ten centimetres are called CubeSats. These were first developed in 1999 to allow students to conduct their own research as part of their studies. Being less expensive to make, they can be used for experiments that are higher risk. This includes riskier orbits that are more likely to lead to a spacecraft's early demise. Because financial loss is lessened, these experiments are more worthwhile. NASA's GeneSat-1 is one example of a CubeSat experiment, which was sent to space in 2006 to test the impact of space conditions on bacterial cells.**

© Alamy

# MEGA PORTS

**Almost everything you consume in your daily life comes through one of these complex facilities**

WORDS **AILSA HARVEY**

**DID YOU KNOW?** At any time, there are around 20 million container ships at sea

One cargo ship can carry up to 24,000 containers

Over 80 per cent of all global trade is carried out by sea, transporting 11 billion tonnes of cargo annually. All of these goods need to be delivered efficiently to land, speedily sorted and sent to warehouses, showrooms, supermarkets and more. This is a massive operation, relying on over 800 active shipping ports around the world. But what equipment and processes keep these huge sites running smoothly?

Cargo ships can't turn up unexpectedly at ports, as they are often working to busy and well-mastered schedules. Instead, the ship's crew needs to communicate with the port to establish a safe berthing procedure and expected arrival time. The cargo contents and final destination is known to dock workers so that a plan can be established and equipment readied in advance.

**Did you know?**

The largest ships can store 745 million bananas

Transporting goods across the water is very cheap, and ports have been in place for thousands of years to assist trading. The oldest port in the world is Byblos Port in Lebanon, which is estimated to have been built in around 3,000 BCE. This port was mostly used for timber shipping across the eastern Mediterranean. As well as providing people and companies with the best products from around the world, ports are also hubs for employment. At some of the world's largest ports, over one thousand people are employed for various operational tasks. In the future, however, most of these jobs are likely to be replaced by smart, autonomous technology, so many people will lose their jobs or may be employed in more technical roles. This will increase the efficiency of ports, reducing their cost to run and limiting mistakes made by human error.

## WORLD'S BUSIEST

**The Port of Shanghai has been the busiest in the world for 13 years running after overtaking the Port of Singapore in 2010. The seaport, situated at the mouth of the Yangtze river, opened in 1842 and has grown to cover an area of 1.5 square miles. From here, over 2,000 ships depart every month, and 500 million tonnes of cargo is handled in a year. There's ample space at Shanghai to receive this huge influx of cargo. Most of the cargo delivered to the port consists of coal, metal ore, petroleum, steel and machinery. There are 19 terminals and over 125 docks built at the site.**

13,546 people worked at the Port of Shanghai in 2021

## TYPES OF SHIPPING PORTS

**INLAND**
Situated away from the coast on rivers or lakes, many inland ports are used in similar ways to shipping ports at the coast. However, the types and sizes of vessels that can use them are more limited. Some are solely for recreational use.

**DRY**
Dry ports are land-based, connected to seaports by railway lines and roads. These are essential to ease congestion in some of the main ports. By sorting and storing large cargo temporarily, they free up space at seaports.

**WARM WATER**
A warm water port doesn't freeze over during the winter months. However, not all locations have a climate fit for a natural warm water port. Ports such as those in Finland use icebreaker ships, which are specially designed to sail through ice.

**FISHING**
Fishing ports can be inland or at the coast, but are always found where there is a high abundance of fish. These ports need to maintain controlled fishing rules to make sure that overfishing doesn't take place and deplete resources.

© Alamy / Getty

# PORT TECHNOLOGIES

## Discover the heavy-lifting, cargo-cradling machines that make port processes more efficient

**1 STRADDLING STACKER**
Rubber-tyre gantry (RTG) cranes have wheels on their bases, meaning that they're mobile. This is essential for their role as cargo stackers. They pick up containers and move forward on their wheels to stack them neatly on top of other containers, being controlled remotely by an operator. Their wide build allows them to straddle multiple rows of containers, while the lifting component of the crane moves horizontally to align with the desired stack.

**2 TERMINAL TRACTOR**
These vehicles are built to carry cargo containers individually around a port – from the lower sections of the ships to cranes and from cranes to storage facilities. Being relatively small compared with the other on-site machinery, terminal tractors can navigate tighter corners and efficiently transport each piece of cargo from one section of the port to another.

**3 MATERIAL HANDLER**
These vehicles have a crane arm overhanging their front. This puts the action right in front of the driver as they control the material handler's movements. At the end of the crane's arm is a long magnet that covers most of a cargo container's upper surface area. When turned on, the strong magnet attaches to the container so it can be lifted and moved elsewhere. The flexible arm can be lowered into ships and reached upwards to collect cargo from a range of heights.

**4 RAILWAY CONNECTION**
Cargo containers are loaded onto specially designed freight trains to be transported to distribution centres. These centres are where the cargo is individually packaged according to specific orders and sent to customers and consumers.

**5 CONTAINER CRANE**
Tall cranes need to tower over the largest ships that enter a port. This helps cargo get removed from ships safely and easily. Stacks up to 12 containers high can be packed onto these vessels.

**6 AUTOMATED GUIDED VEHICLE**
After being loaded with cargo, fully automated vehicles can transport containers between the quayside and the container yard. Many of these vehicles can be programmed to work simultaneously in some ports, reducing laborious jobs. These sometimes work in tandem with autonomous RTG cranes.

**7 FORKLIFT**
These can raise heavy cargo high above the vehicle using hydraulic force. The operator controls the height the cargo is raised depending on how tall the stack of containers is.

### Did you know?

97 per cent of shipping containers are made in China

**DID YOU KNOW?** Container ship engines are 1,000 times more powerful than a typical family car

# 5 FACTS SMART PORTS

**1 DIGITAL TWIN**
**ROTTERDAM, THE NETHERLANDS**
The Port of Rotterdam has an accurate digital twin, a virtual computer model that includes all the statistics of the port's movements and earnings. It can be used to test the outcome of different scenarios before putting changes in place.

**2 POLLUTION TRACKING**
**HAMBURG, GERMANY**
The Hamburg Port Authority uses weather sensors to track the pollution levels in the air surrounding the port. The sensors relay levels of sulphur dioxide, nitrogen dioxide and fine dust particles to show how different operations impact the environment.

**3 SUSTAINABILITY**
**ANTWERP, BELGIUM**
Antwerp is considered to be Europe's most sustainable port, with all of its new terminals releasing near-zero emissions. To achieve this, the port is incorporating electricity and hydrogen-powered equipment.

**4 FULLY AUTOMATED**
**SINGAPORE**
Tuas Port in Singapore is on track to become the largest fully automated port in the world when it's completed in 20 years' time. Singapore's prime minister Lee Hsien Loong said the port will "almost double today's volumes" of cargo.

**5 ADVANCED TECH**
**SHANGHAI, CHINA**
The Port of Shanghai has the first centralised remote control and smart command centre. Located 62 miles from the equipment itself, workers can use cameras and controllers to move cranes remotely from inside their office.

Unloading a cargo ship can take one to three days

© Alamy / Getty

# HOW ELECTRIC CAR BATTERIES WORK

## Discover the power sources of the world's all-electric vehicles

WORDS **SCOTT DUTFIELD**

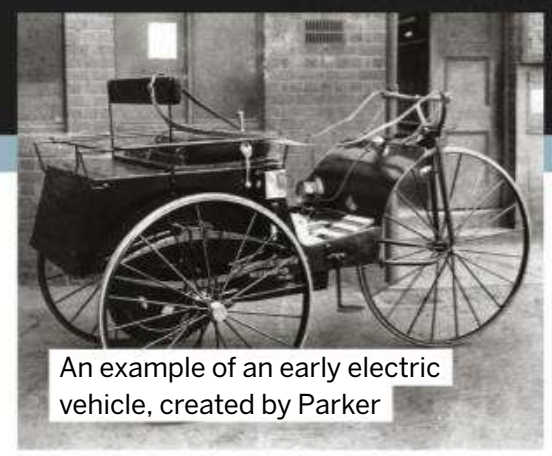
Electrically powered vehicles (EVs) are on the rise, with electric car sales increasing by 40 per cent in 2022. This comes at a time when the world is grappling with the human environmental impact and sourcing more sustainable forms of energy. A typical petrol car emits around 4.6 tonnes of carbon dioxide into the atmosphere per year, but an EV directly emits none. However, EVs are only as clean as their fuel source. For example, in the United States around 61 per cent of American electricity in 2021 was generated by fossil fuels.

Electric cars work in a much more simplified way than their petrol-fuelled alternatives. A typical petrol-powered car relies on an internal combustion engine to release enough force to cause a set of pistons to move, ultimately turning the car's wheels. However, electric vehicles are able to move with a set of rechargeable batteries, typically housed underneath the car, which deliver electricity directly to a motor that turns the vehicle's wheels.

There are several types of electric vehicles on the roads, such as fully electric vehicles and hybrid models that combine a combustion engine and electric propulsion. Hybrid cars are usually powered by a battery that's self-charging during driving, while fully electric vehicles are 'plug-in' models that require the battery to be hooked up to a mains electrical source to recharge after their power has been depleted.

Most of today's electric vehicles are powered by lithium-ion batteries. Also seen in laptops and smartphones, these common batteries work by collecting and releasing the energy produced by the movement of lithium ions. When ions inside the battery move from a negatively charged side to a positively charged side through a solution called an electrolyte, electrons are released to the connected device, giving it power. The battery is out of juice when all the electrons and ions reconvene at the positive side of the battery. During recharging, the ions are sent back through the electrolyte to the negative side, ready to be used again.

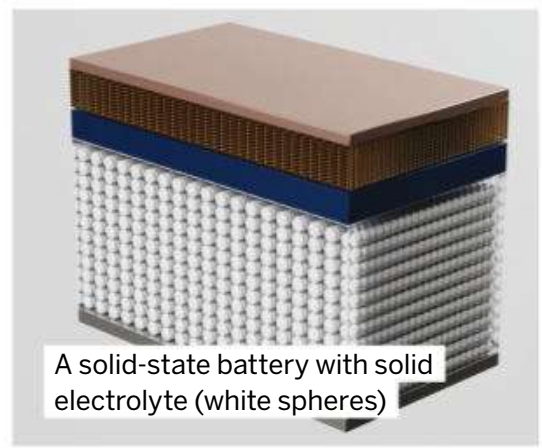
There are around 16,000 locations with public charging ports in the UK



An example of an early electric vehicle, created by Parker

### EARLY EVS

**The first electric carriage was created in Scotland. Between 1832 and 1839, Scottish chemist Robert Anderson constructed the first crudely built prototypes of non-rechargeable battery-powered carriages. Anderson strapped a battery and an electric motor – invented in 1828 by Ányos Jedlik – to a carriage typically drawn by horses. But Anderson's creations didn't catch on, possibly because of the rise in steam-powered alternatives. It wasn't until the late 19th century that more electric carriages emerged. In England, the first electric vehicles came from inventor Thomas Parker and were propelled by lead-acid batteries.**



A solid-state battery with solid electrolyte (white spheres)

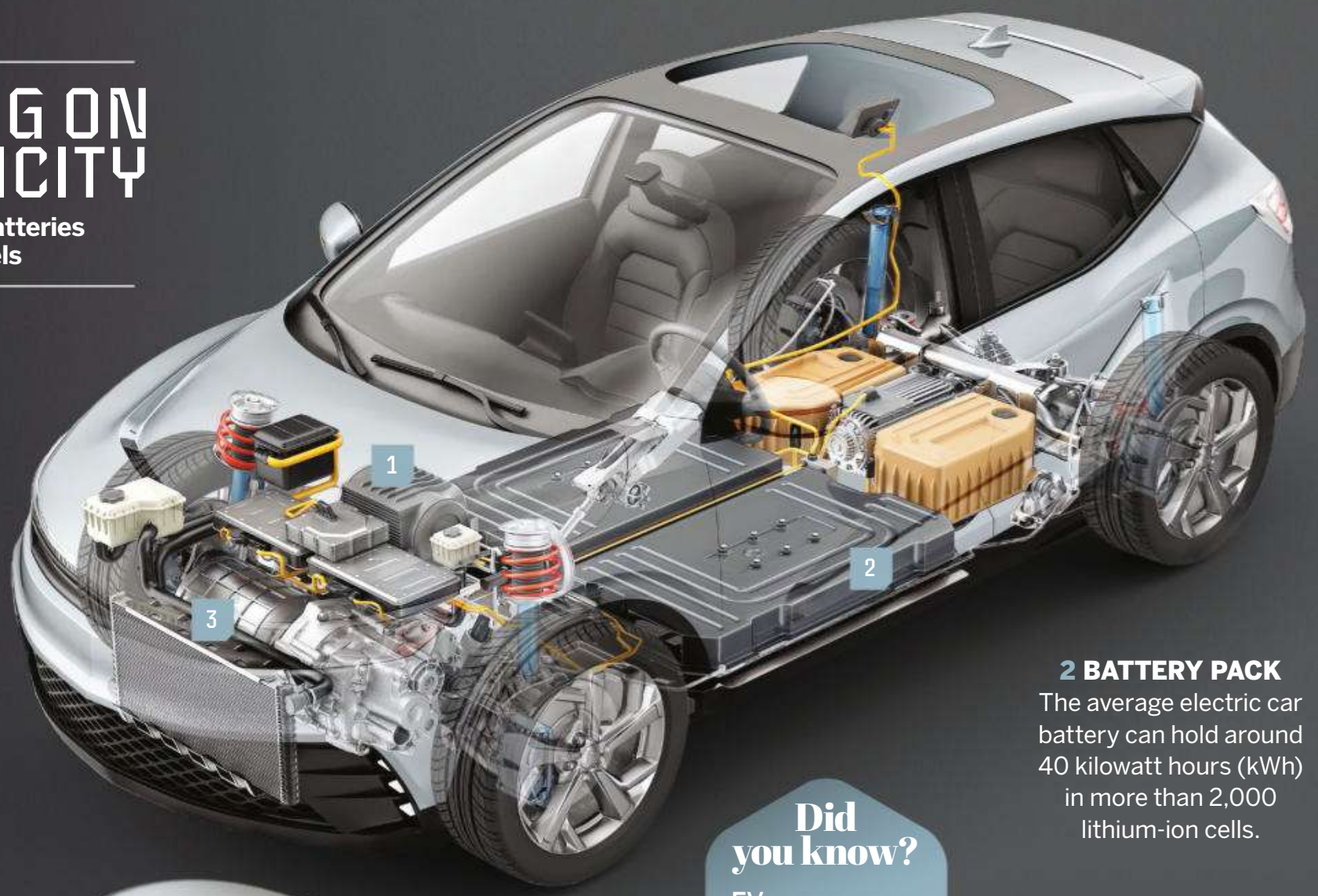
### NEXT GENERATION

**The next advancement could be the creation of the vehicle-compatible solid-state battery. Though there are plenty of benefits to using lithium-ion batteries, they aren't without drawbacks, including energy storage decline over time, overheating and the requirement of flammable liquid electrolytes. Engineers around the world are working on creating the next generation of solid-state batteries that switch fluid electrolytes for solid alternatives such as ceramics, glass or plastics. A solid electrolyte works in the same way as current fluid versions but would increase the energy density of lithium ions in a battery and make them more powerful. A solid-state battery wouldn't produce heat as a byproduct and would remove the need for the internal cooling system seen on current EV batteries.**

**DID YOU KNOW?** There are more than 400,000 electric car charging ports in the UK, including those in homes

# RUNNING ON ELECTRICITY

**How electric batteries turn wheels**



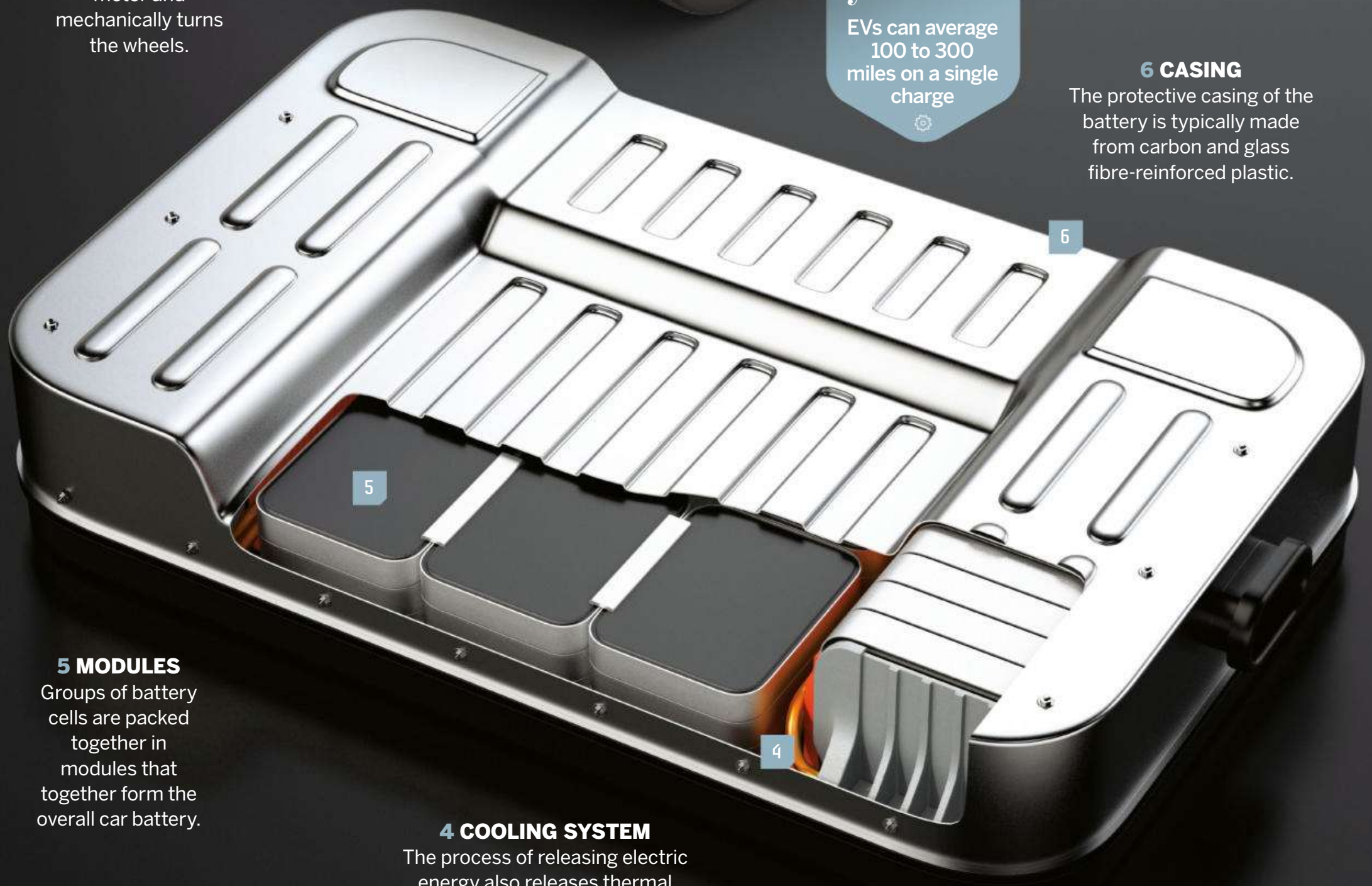

**1 TRACTION MOTOR**
The energy supplied by this EV battery drives the motor.

**2 BATTERY PACK**
The average electric car battery can hold around 40 kilowatt hours (kWh) in more than 2,000 lithium-ion cells.

**3 TRANSMISSION**
The transmission is connected to the motor and mechanically turns the wheels.

**Did you know?**
EVs can average 100 to 300 miles on a single charge

**6 CASING**
The protective casing of the battery is typically made from carbon and glass fibre-reinforced plastic.




**5 MODULES**
Groups of battery cells are packed together in modules that together form the overall car battery.

**4 COOLING SYSTEM**
The process of releasing electric energy also releases thermal energy, so a glycol-based coolant is used to keep EV modules cool.

© Alamy / Getty

# POINTLESS BODY PARTS

## Discover the anatomical echoes of our evolutionary journey to the modern day

WORDS SCOTT DUTFIELD

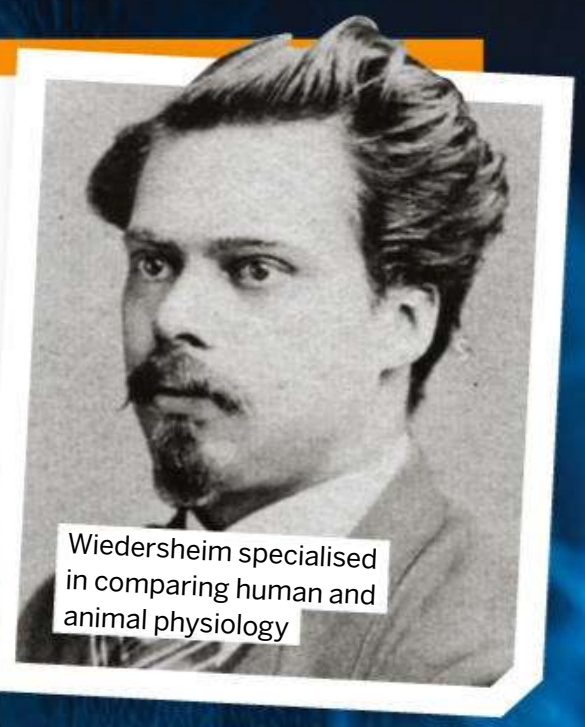
Life on Earth has spent the last 3.7 billion years growing, changing and evolving in response to the changing environment, so it seems likely that there might be some evolutionary leftovers picked up along the way. Vestigial structures are typically organs, tissue or bones that once served a purpose for our ancestors. However, over time their usefulness has waned, such as hind leg bones in whales or wings among flightless birds.

It's largely accepted that an organ or structure that appears to lack a certain function in at least two other closely related species is deemed vestigial. These vestiges aren't always anatomical; they can also be genetic or behavioural. For example, when a baby is born their tiny hands and feet can quickly and robustly grip objects. This is known as the palmar reflex and is thought to be the instinctual leftovers of a time when the babies of our prehistoric ape ancestors had to hold onto their mothers' fur for transport.

Vestigial structures can be useful to scientists tracking the evolutionary journey of some species. As inherited features, vestigial structures allow scientists to piece together the lineage of species by comparing them to functioning anatomy. When they have strong similarities, they're known as homologous structures. Some structures that are now largely redundant for one species were once essential for their ancestors. For example, hoatzin birds (*Opisthocomus hoazin*), found in the tropical forests of South America, are born with tiny claws at the ends of their wings, the only birds in the world to have them. By adulthood the birds lose these claws, but it illustrates their relation to the prehistoric bird archaeopteryx, which used similar claws to capture prey and climb trees.

### POINTING OUT THE POINTLESS

The connection between vestigial organs and evolution was first proposed by Charles Darwin in 1859. In both *On the Origin of Species* and *The Descent of Man*, Darwin outlines the concept of rudimentary organs as common features in nature that once served a purpose, but have lost functionality. Inspired by Darwin, German anatomist Robert Wiedersheim penned a list of 86 vestigial organs "which were formerly of greater physiological significance" in his 1893 book *The Structure of Man: An Index to His Past History*. While the functionality of some of the organs on Wiedersheim's list remain in question, others, such as the thymus and the pituitary gland, can be stricken from a list of vestigial organs.



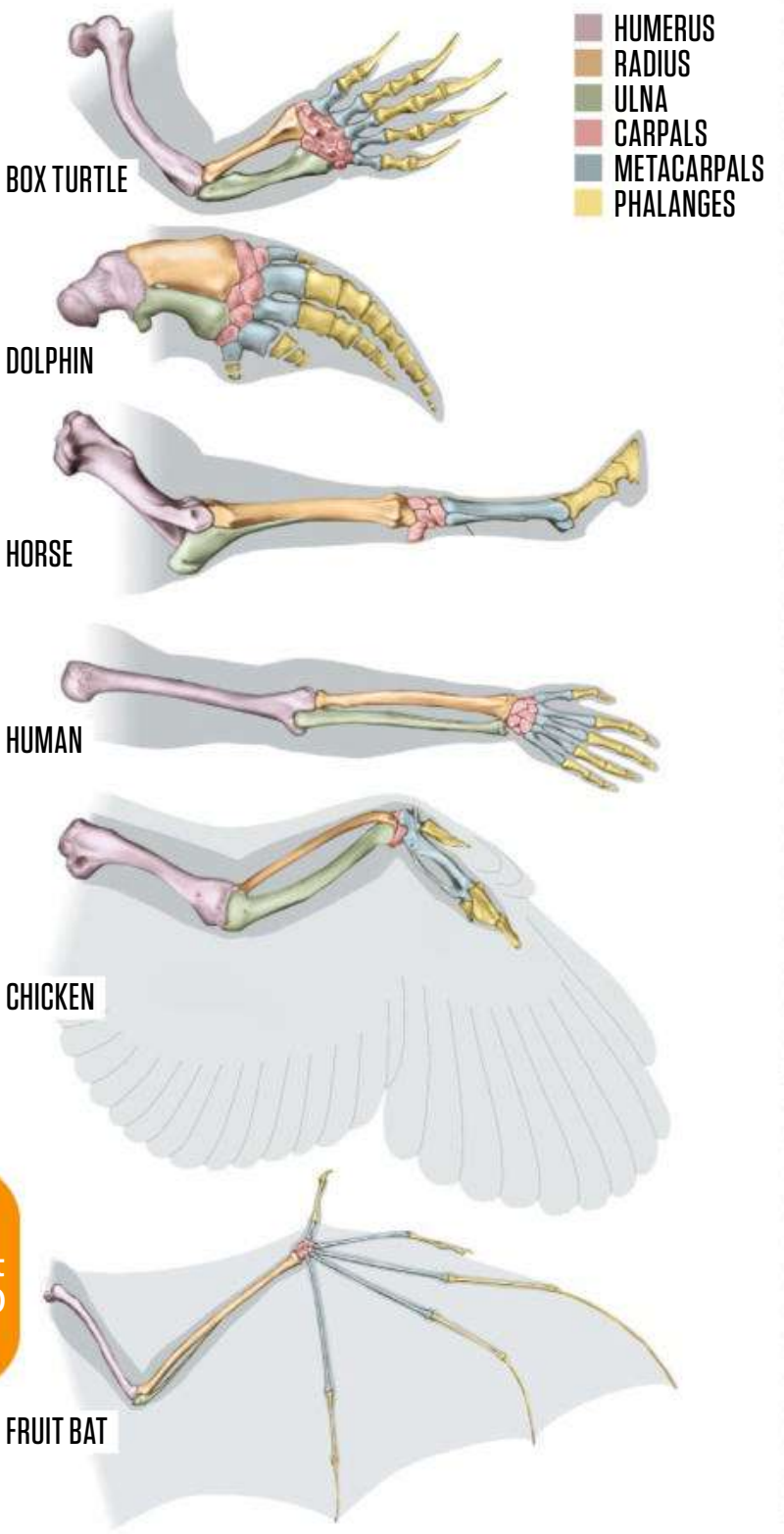
Wiedersheim specialised in comparing human and animal physiology

**DID YOU KNOW?** The first surgical removal of an appendix was performed in 1735

# SAME STRUCTURES, DIFFERENT BEASTS

## How homologous structures help link animal relatives

Homologous structures are anatomical similarities between species that share a common ancestor, whereas vestigial structures are similar but have little to no function. The skeletal structure of the forearm is comparable across a range of species, such as turtle, human, dolphin and bat. Here you can see the different individual bones that make up the forelimb and how they have evolved and changed to function for each animal. However, if one of these homologous structures became nonfunctional, it would be deemed vestigial.




**Did you know?**

*Homo sapiens* first appeared 300,000 years ago

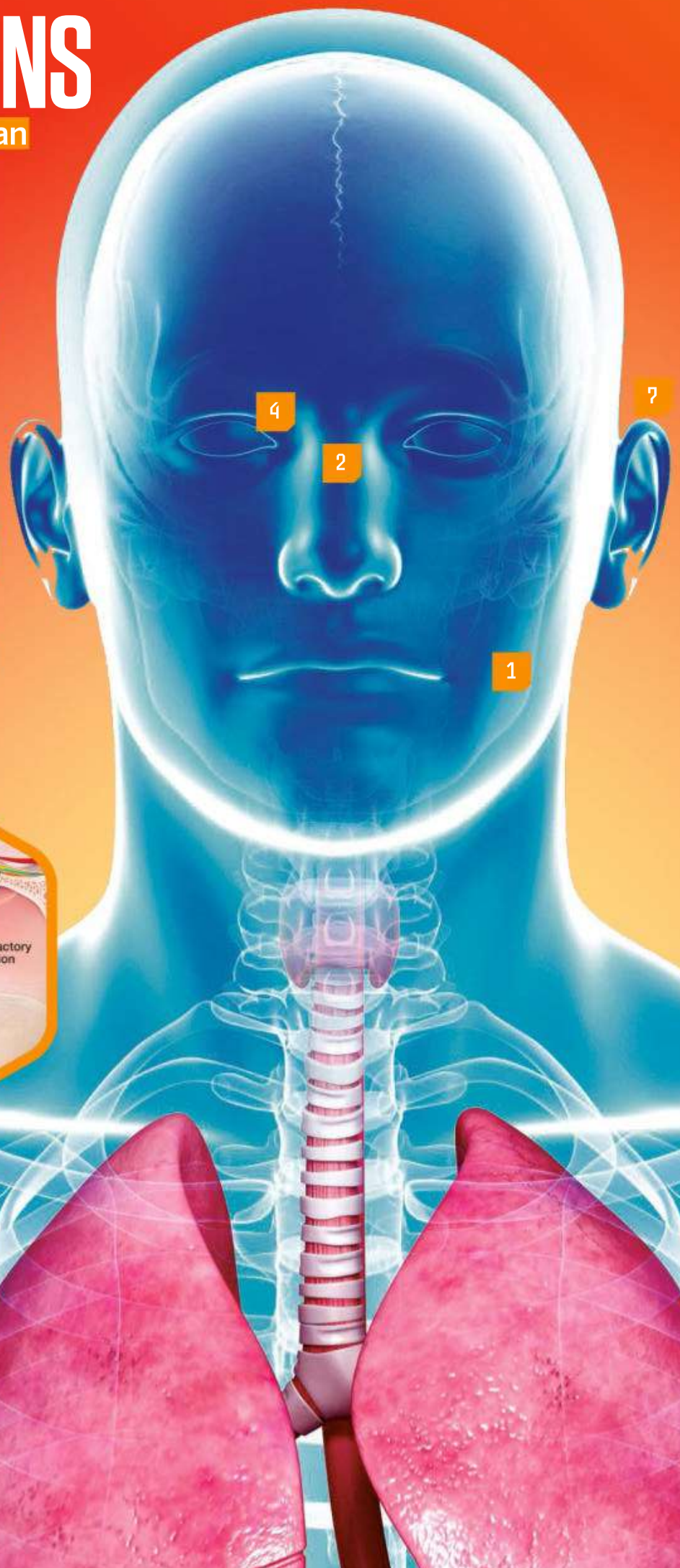
©Getty / Alamy

# REDUNDANT ORGANS

**Are these vestigial structures of the human body truly useless?**

### 4 THIRD EYELID

In the corner of your eye is a fold of a clear membrane called the plica semilunaris. In other animals such as birds and cats, this membrane develops into a wiper-like eyelid, called a nictitating membrane, to protect the eye. For us, the plica semilunaris doesn't form a third eyelid, and is therefore thought to be pointless.




### 7 AURICULAR MUSCLES

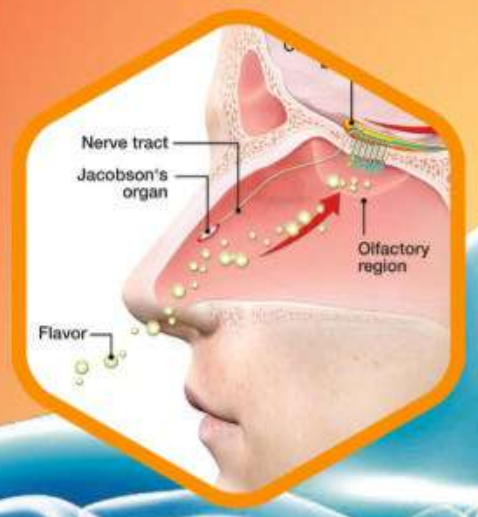
A small portion of people – around ten per cent of the population – have the ability to voluntarily move their ears back and forth by engaging their auricular muscles. In other animals such as dogs and cats, these muscles are used to direct large ears towards the source of a sound. However, humans have generally lost this ability.

### 1 WISDOM TEETH

Sitting at the back of the jaw are our third molars, also known as wisdom teeth. More often than not, as wisdom teeth grow they become impacted, or they get stuck below the surface of the gums and do not emerge. The human jaw is often too small to accommodate these vestigial teeth. However, some research suggests that childhood diets lack hard raw food, such as nuts and vegetables, that stimulate jaw growth.

### 2 JACOBSON'S ORGAN

Also known as the vomeronasal organ, for many animals, such as snakes, the Jacobson's organ is a useful tool for detecting pheromones in the air. The tube-shaped organ can be found on the roof of the nasal cavity, but its functionality is highly contested. Some genetic evidence suggests that it's useless in humans and the genes that code for receptor proteins in the organs are mutated and nonfunctional.




### Did you know?

The coccyx is around four centimetres long

**DID YOU KNOW?**

22 per cent of adults are missing one or more of their four wisdom teeth

3

### 3 GOOSEBUMPS

When you're cold, scared or listening to a great singer, you might experience a strange puckering of the skin called goosebumps. During these moments, tiny muscles beneath the skin known as arrector pili contract, tugging on hair follicles that stand on end. For our furry cousins, making the hair stand up creates air pockets and traps warmth near the body, as well as making them appear larger when threatened. However, humans no longer have enough hair for arrector pili to serve a purpose.

6

### 6 PALMARIS LONGUS

A strip of muscles that runs between the wrist and the elbow, called the palmaris longus, is a remnant of a time when prehistoric humans used it for support while tree climbing. Although the muscle is involved with the flexibility of the wrist, it's estimated that for around 15 per cent of the population this muscle is missing, without any impedance to their wrist flexibility or movement.

### 8 THE APPENDIX

Connected to the body's large intestine is a thin tube called the appendix. For decades scientists have debated whether or not this small extension of the digestive system serves a purpose and whether or not it's a vestigial structure. Darwin was the first to suggest its pointlessness, saying it may have once been used to digest robust plants in a similar way to the working appendix of modern-day rabbits. However, scientists have discovered that in humans it may be involved in making and training immune cells for the body's immune response to pathogens.

8

5

### 5 THE TAILBONE

Around 25 million years ago, prehistoric humans lost their tails. However, we've retained a small vestigial tailbone called the coccyx. During our development, foetuses grow a tail like many other animals. However, after eight weeks of gestation the tail cells self-destruct and are removed, leaving humans tailless. Nevertheless, the tailbone remains fused to the vertebrae.

© Alamy / Getty

# VESTIGIAL KINGDOM

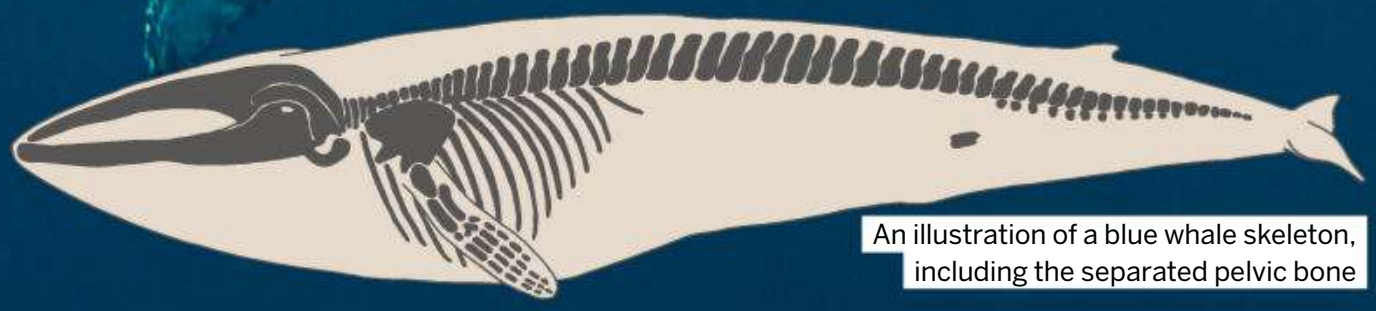
**Plants and animals that have clung onto some of their ancestral anatomy**

**Did you know?**

A whale's closest living relative is a hippo

## WHALE LEGS

The evolutionary journey of the whale has been long, involving emerging out of the water onto land and then returning to the ocean around 50 million years ago. Common ancestors of cetaceans – the group of animals that includes whales, dolphins and porpoises – were amphibious creatures that walked over land and into the ocean on four legs. Over millions of years those legs evolved into fins, leading to the existence of modern-day whales. However, a piece of their land-dwelling past remains in their bodies – a pelvic bone. The free-floating, shrunken bone isn't attached to the whale's vertebrae and sits among muscles. Although these bones no longer form part of a leg, they may serve some other purpose. Some studies suggest that because the pelvic bone is attached to muscles attached to whale genitalia, it may support reproductive success.



An illustration of a blue whale skeleton, including the separated pelvic bone

## PRETTY BUT POINTLESS

During spring you might see the vibrant-yellow petals of dandelion plants (*Taraxacum officinale*) sprouting up around gardens and fields. Unlike other plants that have evolved bright and beautiful petals to attract pollinators to reproduce, dandelions are able to do it alone. Through a process called apomixis, dandelions can reproduce asexually, creating seeds that are genetic clones of themselves. So although dandelions grow petals, pollinators aren't required for a dandelion to grow seeds, but dandelions still supply them with food through nectar.

## SLUG SHELLS

Around 150 million years ago, land snails evolved from their aquatic ancestors, and shortly after diverged into land-dwelling snails and the shell-less slug. However, slugs aren't technically without a shell. For snails to build their shell homes, they take in calcium carbonate from their environment. Then an organ called the mantle crystallises the carbonate and makes a hard shell. Slugs do have a vestigial mantle. However, it does not produce the spiralling shell seen on the backs of snails. Instead it makes a tiny shell beneath the skin of slugs.

Slugs do have shells, they're just hidden from view

**DID YOU KNOW?** Ostriches descend from the flightless elephant bird, which was three metres tall

## SEEING WITHOUT EYES

Blind cave fish (*Astyanax mexicanus*) are found off the coast of Mexico, but look a little different to their surface-swimming cousins, mainly because they are missing a pair of eyes. When you're swimming at the bottom of a pitch-black cave, a good pair of eyes isn't exactly a necessity, so these blind cave fish got rid of them.

During the first 24 hours of embryonic development, these fish do grow a rudimentary eye. However, shortly after the underdeveloped eye is cut off from the blood supply and a layer of skin forms over it. Researchers have discovered that a slight mutation in the cave-dwelling fish has caused the formation of the vestigial eye structure hidden beneath the skin. Instead of relying on their vision, cave fish pucker their mouths and release bursts of suction to monitor changes in water pressure in a similar way to how bats detect sound waves for echolocation.

## SNAKE LEGS

**During the Cretaceous period, around 100 million years ago, snakes lost their legs and evolved their serpentine method of movement. It's thought that the lizard ancestors of snakes born with smaller legs were able to navigate different types of terrain and enter new areas that others couldn't. Over time these ever-decreasing leg lengths led to their complete removal.**

**However, some snakes have kept small pieces of hind leg bones from their lizard ancestors. Pythons and boa constrictors have tiny bumps on the sides of their pelvis, called pelvic spurs, where the legs would have once developed. These vestigial structures aren't connected to the snakes' vertebrae and instead sit between the muscle mass of the animal.**

The pelvic spurs of an albino Burmese python

## 5 FACTS FLIGHTLESS BIRDS

**1 OSTRICH (*STRUTHIO CAMELUS*)**
Although their wings can no longer fly, ostriches have repurposed them for balance and navigation when they run at speeds of up to 43 miles per hour. Males also use their impressive wings during courtship displays to attract a mate.

**2 KIWI (*APTERYX AUSTRALIS*)**
Instead of the light, hollow wings of other birds, kiwis have tiny marrow-filled wings that are around three centimetres long and are hidden beneath their fur-like feathers. DNA evidence suggests kiwis descended from prehistoric birds that flew from Madagascar to New Zealand.

**3 STEAMER DUCK (*TACHYERES*)**
Out of the world's four species of steamer ducks, three are flightless. During the Late Pleistocene epoch, the flightless species diverged from their flying relatives. Some of the species found in South America have been seen using their wings like paddles in the water.

**4 KĀKĀPŌ (*STRIGOPS HABROPTILUS*)**
Native to New Zealand, these flightless parrots use their short wings for balance as they climb and leap from trees in the forest. Due to their inability to fly, their feathers have also become soft and are unable to sustain flight.

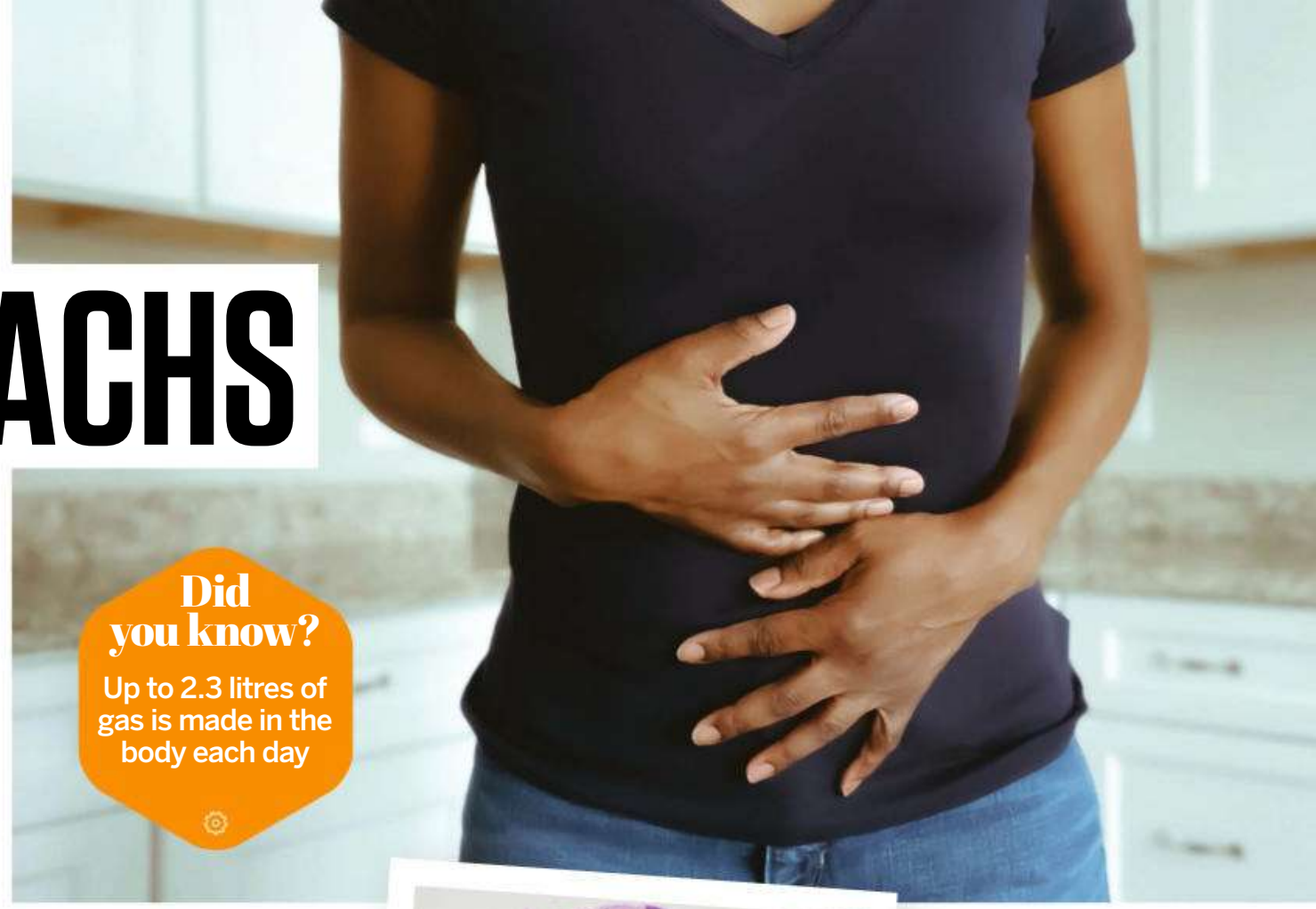
**5 CASSOWARY (*CASUARIUS*)**
Although cassowary species can't fly, they use their wings to help them navigate through the forest. At the ends of their tiny wings are long, bare quills that they use to move obstacles, such as tough thorns and branches, out of their way.

© Alamy / Getty

# WHY STOMACHS RUMBLE

## What's your gut trying to tell you with its growling and grumbling?

WORDS **AILSA HARVEY**



**Did you know?**

Up to 2.3 litres of gas is made in the body each day

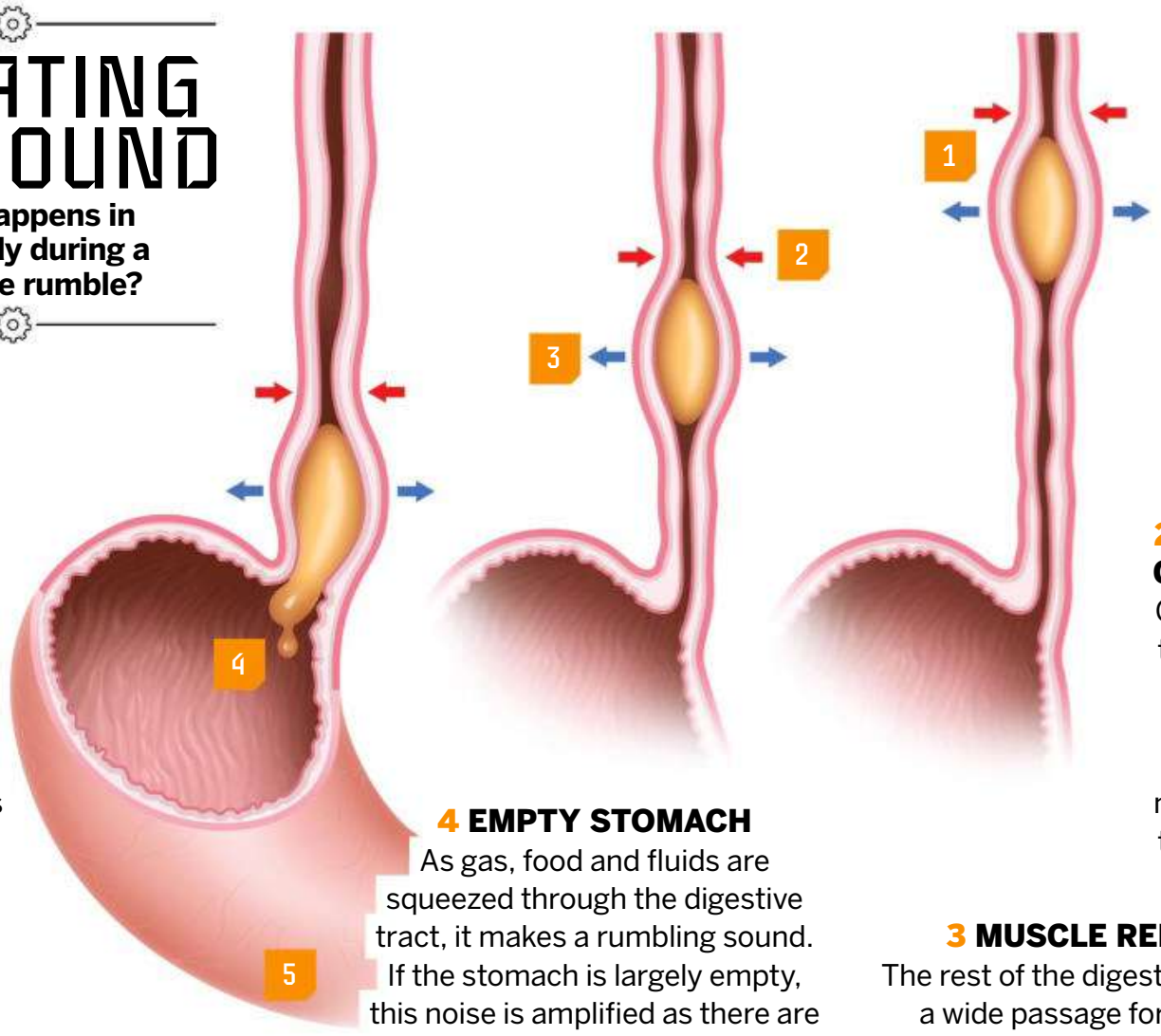
Most of the time your stomach doesn't make its presence known. But every now and then, especially if you're sitting in a quiet room, it might begin talking to you. This could be in the form of a rumble, gurgle or tiny roar. So what is this organ trying to tell you? The technical term for these abdominal noises is borborygmi. Most of the time, borborygmi are caused by a combination of an empty stomach and activity in the digestive system. This means that the noise can serve as a beneficial reminder that you haven't eaten much food in a while.

However, stomach rumbles aren't exclusively caused by hunger. When they occur without any discomfort or pain, it's just a natural noise made by your body processing its contents. If this changes and growls are coupled with discomfort, your gut is communicating that something isn't right. This could be an intolerance to a certain food, while the addition of bloating could indicate indigestion or, when occurring regularly, irritable bowel syndrome. If discomfort continues in the abdomen, you should consult a doctor to find out its cause and how to treat it.

This smooth layer of muscle (dark pink) in the small intestine contracts to push food through

## CREATING THE SOUND

**What happens in your body during a digestive rumble?**




**1 FOOD'S JOURNEY**
As soon as you swallow food or fluid, your digestive tract begins a process called peristalsis to push it through the body.

**2 INVOLUNTARY CONTRACTIONS**
Circular muscles in the oesophagus or intestine contract behind the food, controlling its movement through the digestive tract.

**3 MUSCLE RELAXATION**
The rest of the digestive tract remains a wide passage for food to travel through, with the muscles relaxed.

**4 EMPTY STOMACH**
As gas, food and fluids are squeezed through the digestive tract, it makes a rumbling sound. If the stomach is largely empty, this noise is amplified as there are less contents to muffle the sound.

**5 VOLUME DIFFERENCE**
Rumbling doesn't just occur in the stomach, but throughout the whole digestive tract. In narrower sections there is less space for echoing sound waves.

## 5 WAYS TO REDUCE RUMBLING

**1 DE-STRESS**
If you are stressed about something, your body releases hormones that increase the muscle contractions of the digestive tract.

**2 EAT SOME FOOD**
As the most common reason for a rumbling sound is an empty stomach, listen to your body's call for food.

**3 SIP WATER**
Drinking water helps your body break down food, reducing the gas created during digestion.

**4 EAT SLOWER**
If you eat too quickly, you'll swallow more air with your food. Taking your time can prevent gas buildup.

**5 REDUCE GASSY FOODS**
Consuming high-fibre foods such as beans or carbonated drinks increases your chances of a rumbling stomach by producing gas.

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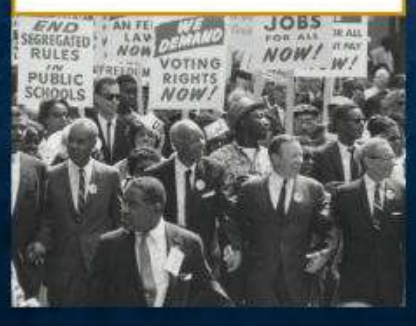
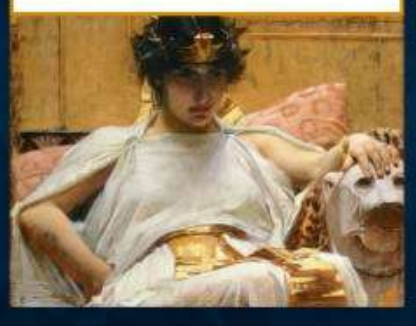
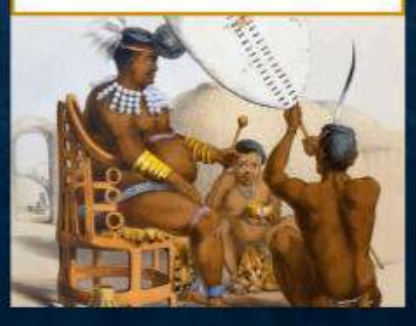
|  | |  | |  |

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# TECHNOLOGY

**DID YOU KNOW?** Modern smoke bombs use pellets to release smoke over a 5,000-metre range

# INSIDE THE BOMB FACTORY

## We take a tour of a world-leading munitions factory to find out how bombs and bullets are made

WORDS **MIKE JENNINGS**

It's not every day that you get invited to visit a bomb factory, but that's exactly what happened to **How it Works**, so we jumped in the car and headed to Washington, in the north of England, to visit a plant operated by BAE Systems. Drive up to the building and you'd be hard-pressed to guess what gets made there. There's a security gatehouse, but beyond that it just looks like any other factory. On the inside, though, it's a very different story. Most of the armaments produced at Washington are sold to the British Ministry of Defence (MoD), but around 25 per cent of the factory's output is sold to militaries around the world – on the day we visited, the munitions on show were heading to Germany. The BAE group produces loads of products – from vast tank shells to tiny bullets – and the plant at Washington concentrates on medium-sized munitions, including 81mm mortar shells and 155mm bombs that are currently used in Ukraine.

**Did you know?**
BAE Systems was founded in November 1999

BAE has a £2.4 billion ($2.9 million) contract with the MoD that's set to last until 2038 called the Next Generation Munitions Solution (NGMS). It should allow the MoD to manufacture more arms in the UK, which reduces costs, makes manufacturing more secure and enables

155mm shells are used in the Archer Mobile Howitzer, a 33-tonne gun vehicle

BAE's Washington plant looks unassuming on the outside, but it's a world-leading armament facility

### FROM WAR TO WASHINGTON

**BAE's predecessors have been making mortar, artillery and tank ammunition in the North East of England since 1916, when the firm opened its first factory in a town called Birtley. That first facility employed 3,800 people, and 3,500 of those were Belgian soldiers who arrived in Britain after fighting on the front lines in World War I. At the time, two munitions factories were built, mostly staffed and managed by Belgian teams, because Belgium had a fantastic reputation for manufacturing armaments. The Belgian community in the North East was dubbed Elizabethville, and a new village was built alongside the factories. By 2009 an upgraded munitions factory was required, and in 2012 BAE moved from Birtley to Washington. The new £75-million ($90.3-million) factory sits on the site of an old Dunlop tyre plant next to a luxury car factory and currently employs 340 people.**

©BAE

**Left:** The Archer can fire three 155mm rounds in 20-second bursts, with a range of 30 miles

**Below:** BAE's Glascoed site was chosen because it's secluded, and thus hidden from enemy bombers

companies like BAE to export more products abroad. Over the course of the NGMS project, BAE plans to invest £91 million ($109.5 million) into equipment and improvements, and the biggest individual investment so far is a £5 million ($6 million) automated line at the Washington plant, which we saw during our factory tour. The NGMS project isn't just about crunching numbers, either. BAE is investing in new methods for mixing explosive material, updated explosive mixtures, lighter shell casing and improved accuracy across its production lines.

Before exploring the munitions factory, we had to squeeze our feet into steel-capped boots and put on shatter-proof safety goggles. We had to sit through a safety briefing too, and no wonder – the factory floor is a busy, loud place. BAE's facility is divided into three broad areas: one for forging a rectangular metal 'billet' into the rough shape of the shell, a second area for refining that 'bottle' into the precise design required and a third to finish the exterior of each unit. The forge is an absolute beast – it's certainly not the kind of small unit where one person stands with a hammer. It cost £13 million ($15.7 million) to build, weighs 250 tonnes and it's one of the most advanced devices in the world. That's no surprise when you see it in action: robots grab the dull metal billets and heat them until they're so hot that they're glowing and you can't get near them without feeling the extreme temperatures. More robots grab the heated blocks and start to squeeze, stretch and form the metal into a hollow bottle shape that will eventually become a 155mm calibre artillery round.

**Did you know?**

BAE has provided the MoD with munitions since 1940

It's a remarkable process to witness. Robots move in smooth and synchronised motions, steam hisses from machines and the white-hot metal progresses to another machine to cool down so humans can handle it again. The forge is the kind of thing you're used to seeing on industrial planets in *Star Wars*, not on the outskirts of Sunderland. At this point, expert technicians refine each shell on production lines of expensive, sophisticated machines – and the munitions are kitted out with different paints, markings and components. While the manufacturing process isn't finished at that point, the story is over for the Washington plant – the shells head to Glascoed in Wales to be filled, assembled and shipped at a different munitions factory.

# TYPES OF AMMUNITION EXPLORED

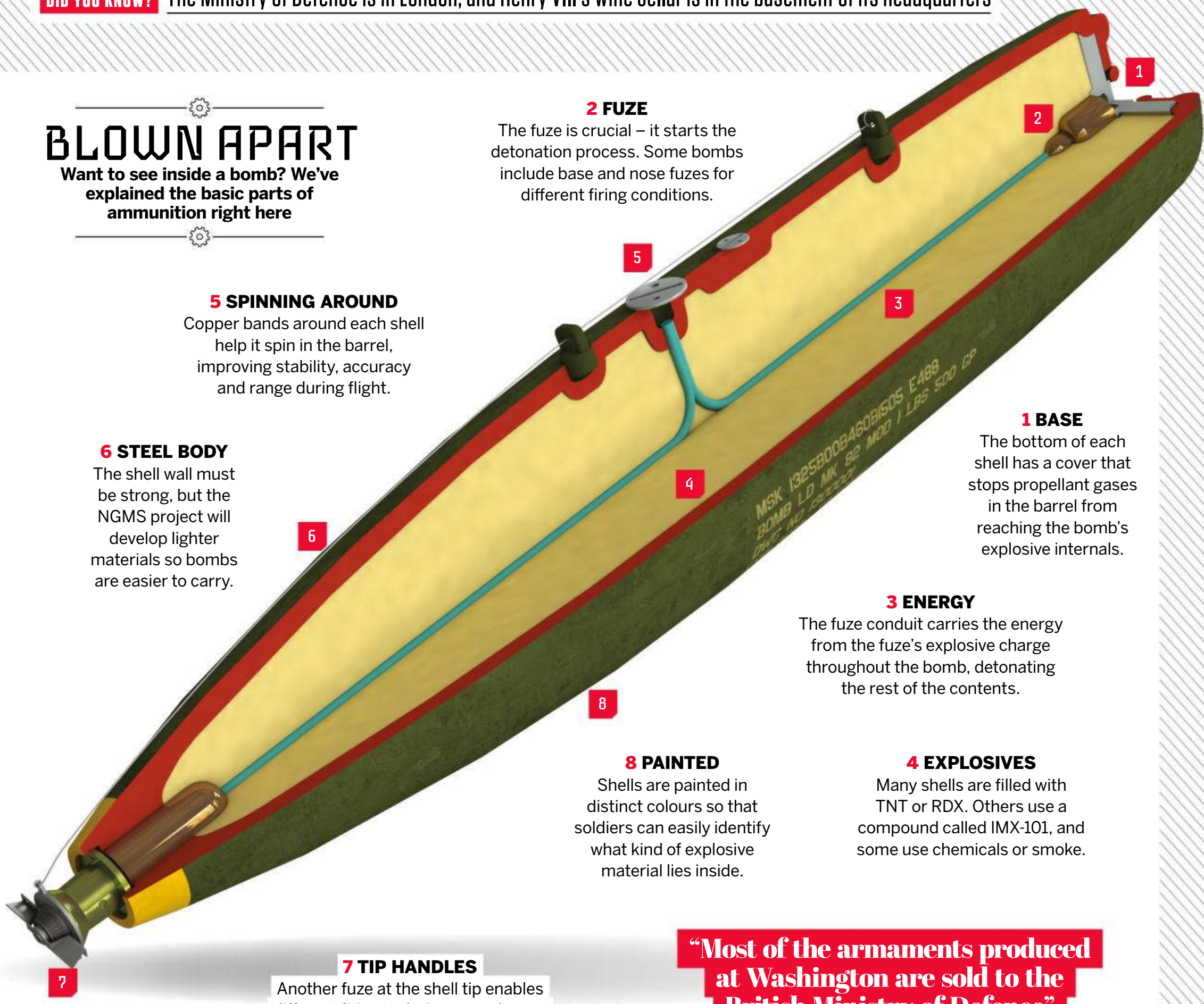
**SMALL ARMS AMMUNITION**
These bullets range in size from 5.56mm to 7.62mm and work inside handheld guns. Tracer, armour-piercing and high-performance designs are available, and laser gauging ensures high accuracy in manufacturing.

**CASED TELESCOPED AMMUNITION**
These 40mm shells are a world-first design, replacing existing 30mm rounds while offering more power. They're fired from vehicles and come in armour-piercing and anti-air varieties.

**DID YOU KNOW?** The Ministry of Defence is in London, and Henry VIII's wine cellar is in the basement of its headquarters

# BLOWN APART

**Want to see inside a bomb? We've explained the basic parts of ammunition right here**




**1 BASE**
The bottom of each shell has a cover that stops propellant gases in the barrel from reaching the bomb's explosive internals.

**2 FUZE**
The fuze is crucial – it starts the detonation process. Some bombs include base and nose fuzes for different firing conditions.

**3 ENERGY**
The fuze conduit carries the energy from the fuze's explosive charge throughout the bomb, detonating the rest of the contents.

**4 EXPLOSIVES**
Many shells are filled with TNT or RDX. Others use a compound called IMX-101, and some use chemicals or smoke.

**5 SPINNING AROUND**
Copper bands around each shell help it spin in the barrel, improving stability, accuracy and range during flight.

**6 STEEL BODY**
The shell wall must be strong, but the NGMS project will develop lighter materials so bombs are easier to carry.

**7 TIP HANDLES**
Another fuze at the shell tip enables different firing techniques, and some tips also have handles to make transport easier.

**8 PAINTED**
Shells are painted in distinct colours so that soldiers can easily identify what kind of explosive material lies inside.

**"Most of the armaments produced at Washington are sold to the British Ministry of Defence"**

**81MM MORTAR BOMB**
Mortars are lightweight, handheld cannons. Their 81mm shells are available in high-explosive designs alongside smoke-filled and illumination variants, and infrared shells help soldiers using night-vision goggles.

**120MM TANK AMMUNITION**
As the name suggests, these shells fire from tanks and function in the widest range of climates. They have anti-armour capabilities and high-explosive properties for maximum impact.

© Alamy / BAE / Illustration by Adrian Mann

# PRODUCTION

**Here's how a bomb factory navigates the tricky bomb-building process, from start to finish**

**Did you know?**

BAE produces a million small arms rounds each day

## 1 DESIGN AND CONQUER

BAE Systems needs to design bombs before they can get building. Expert engineers get the job done in the office using complex software packages.

## 2 HEATING UP

Rectangular slabs of steel, called billets, are heated to 1,100 degrees Celsius so they're malleable enough to mould properly. This process is called induction, and the metal is red-hot after it emerges.

## 3 TAKING SHAPE

Once the metal is pliable, machines press and extrude the material until it forms the shape of a large cylinder. This part of the process only takes 60 seconds.

## 4 COOLED AND BLASTED

Bottles are cooled and shot-blasted to smooth the surface. The shell ends are heated to 1,150 degrees Celsius and compressed into a perfect tip in a process called swaging.

## 5 COLOUR CODING

At the other end of the factory, projectiles are painted and fitted with their copper rotation bands. Quality is checked before the shells are packed for transport.

## 6 FILLING UP

Staff at BAE's plant in Glascoed, Wales, fill the shells. The MoD partially chose the site because its damp microclimate was ideal for handling dangerous explosives.

## 7 PACKED AND STACKED

Shells aren't just filled at Glascoed – final assembly takes place here, including any extra modules required by customers. The bombs are carefully packed for final shipping.

## 8 SHELL TESTING

Some shells are sent to Ridsdale in Northumberland, where BAE tests its weaponry. It's a full-scale firing range where technicians can replicate battlefield conditions.

**DID YOU KNOW?** A standard 155mm shell has a range of 14 miles, but rocket-assisted shells can cover almost 18 miles

## EXPLOSIVE REACTIONS

**Explosions work because of complex chemical reactions that rapidly produce large quantities of gas. Take TNT, which is one of the oldest explosive materials. Its scientific name is 2,4,6-trinitrotoluene, and this explosive works by changing solid materials into a hot, expanding gas in an aggressive thermodynamic reaction. Its reaction produces carbon monoxide, carbon dioxide and nitrogen, and TNT's explosive nature doesn't just come from its pure energy output – it's the incredible speed at which it detonates, too.**

**Another popular explosive, RDX, is called cyclotrimethylenetrinitramine and is produced by the nitrolysis of hexamine with nitric acid. BAE has also developed a substance called IMX-101, and the US Army uses this instead of TNT in its incendiary munitions. It's safer to store and handle, but just as effective. No matter the material, safety is paramount when handling explosives, which is why companies like BAE take so much time to get things right when building the latest bombs.**

# HEAVY-METAL ENGINEER

**Martin Coats is a graduate engineer at BAE. Here's how he got his start**

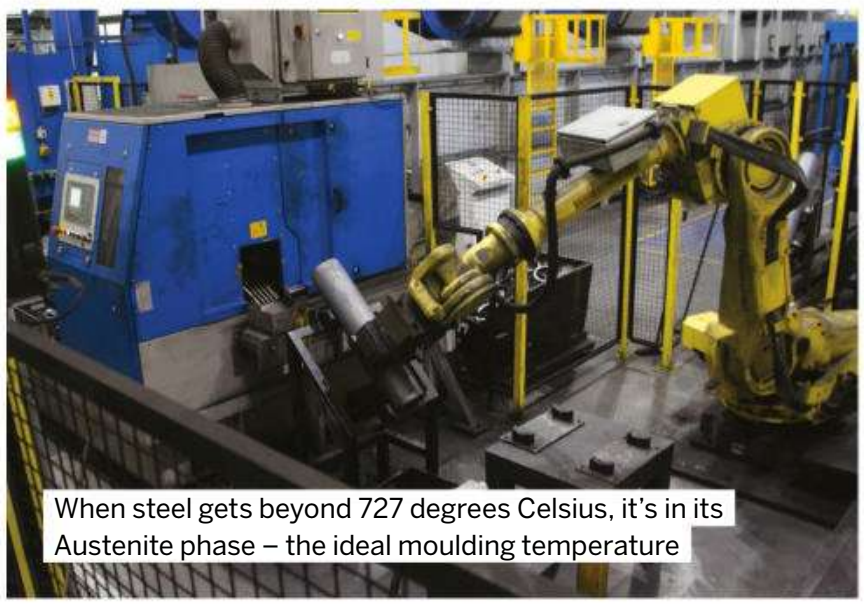
**How did you get started, and what do you do at BAE?**
I studied mechanical engineering at university, and I had an industrial placement at a local company. After that I got involved with materials research and simulation, which is where I saw this role. I applied for BAE's graduate scheme, and here I am. I support the shop floor; I figure out what systems we need for new products and how we maintain current systems. I'm working on Next Generation Adaptable Ammunition, which is really exciting. From a metallurgy point of view, we're trying to soften steel so it forges easier. The induction heater expands the lattice within the material to weaken bonds between crystals so we can form the parts in different presses and punches. But you need to align the grains too, because aligning grains improves the result.

**What's your favourite part of the job?**
The people, by a mile. Everyone has been welcoming. I've always wanted to be an engineer and it's fascinating to be involved in these projects, but the best thing is the people.

**How does someone get into engineering?**
Go for it, and don't be scared. Get as much experience as you can, ask questions, take whatever lessons you need. Try new things. I remember taking my bike apart – I had to do that to go riding, but it gave me a keen interest in how things work. I remember being young and intimidated because I was never the smartest person in class, but there's a place for everyone in engineering. A lot of people look the same around here, so it's really important we get new faces from new backgrounds. They can bring different experiences and approaches because that's how we solve problems. If we have the same people coming in, we just get the same solutions.

Coats specialises in metallurgy and non-destructive testing, with both subjects vital for bomb-building

Munitions manufacture and design requires lasers because precise control means reliable results


When steel gets beyond 727 degrees Celsius, it's in its Austenite phase – the ideal moulding temperature

© BAE / Mike Jennings / Wiki: Martin Coats/LinkedIn

# HOW WIND FARMS WORK

## This technology uses turbines to convert great gusts into electricity

WORDS **AILSA HARVEY**

Burbo Bank Wind Farm in Liverpool Bay covers 15.4 square miles

On a particularly windy day, you may be taken aback by the force at which Earth's air can push against you. This energy is kinetic, but with the help of technology it can be converted into electrical energy. Wind farms are areas of land or sea that are covered with an array of turbines that look like giant windmills. When the wind blows through the farm, the turbine blades turn, spinning a series of huge magnets. This converts the kinetic energy into electrons, which are carried into an electrical circuit. As this happens, electricity is formed. You can think of wind turbines as the opposite of an electric fan: a fan uses electricity to turn blades and generate a breeze, while turbines reverse this process. The best places for wind farms to be built are areas that receive the most wind. Some examples include hilltops, places where there are no obstructions, gaps in mountains where wind is funnelled in strong gusts and large, open plains of land or water.

Wind turbines are between 30 and 50 per cent efficient. This means that they don't capture all of the wind's energy. If they did, the wind would drop completely after blowing through a wind farm's turbines. Although the air around them is always moving slightly, as wind is produced by the uneven heating of the planet, this doesn't mean that wind turbines are always moving. For turbines to function, most require a wind speed of nine miles per hour or greater. In the UK this occurs around 80 per cent of the time, meaning that wind energy is fairly reliable as a naturally occurring and renewable energy source in Britain.

**Did you know?**

**Wind energy doesn't use any water**

Gansu is also known as the Jiuquan Wind Power Base

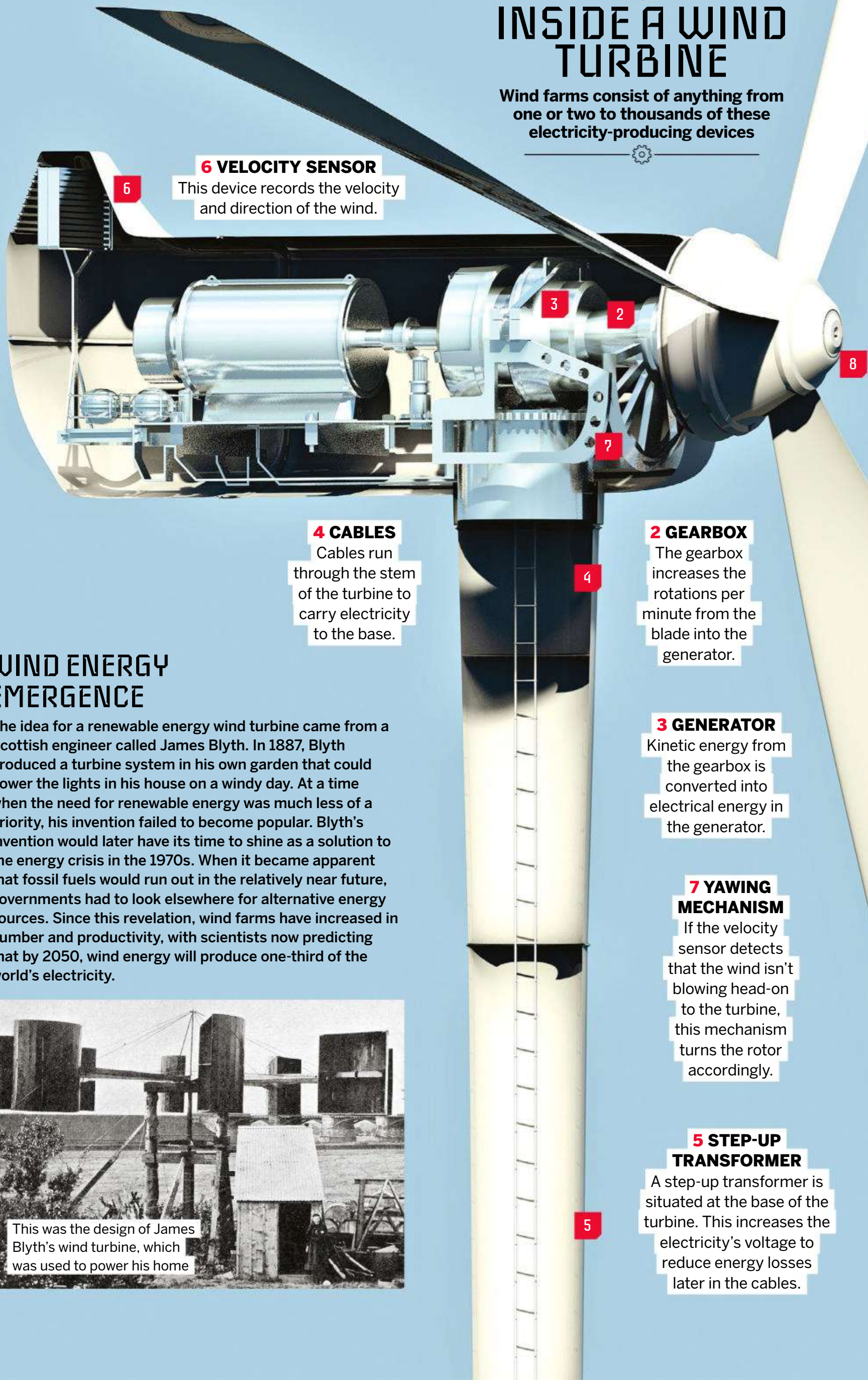
### WORLD'S LARGEST WIND FARM

**In 2010, 3,500 turbines were installed as part of the Gansu Wind Farm at the edge of the Gobi Desert in China. And this wind farm isn't stopping there: it will comprise 7,000 turbines when fully completed and generate 20 gigawatts – enough to power several large cities at minimum. In the UK, another giant wind farm named Hornsea Two is producing enough electricity to power over 1.4 million homes. There are 165 turbines making up the offshore wind farm, which is situated off the coast of Yorkshire. Next to this is another wind farm called Hornsea One, which when combined with Hornsea Two covers an area of 772.2 square miles.**

**DID YOU KNOW?** An average wind turbine blade is 60 metres long

# INSIDE A WIND TURBINE

**Wind farms consist of anything from one or two to thousands of these electricity-producing devices**



**6 VELOCITY SENSOR**
This device records the velocity and direction of the wind.

**1 AERODYNAMIC BLADES**
Aerofoil blades make the turbine more efficient, as their aerodynamics lift the blades more easily through the air.

**8 BLADE TILTING**
A mechanism in the front of the turbine tilts the blades to the optimum angle according to wind velocity.

**4 CABLES**
Cables run through the stem of the turbine to carry electricity to the base.

**2 GEARBOX**
The gearbox increases the rotations per minute from the blade into the generator.

**3 GENERATOR**
Kinetic energy from the gearbox is converted into electrical energy in the generator.

**7 YAWING MECHANISM**
If the velocity sensor detects that the wind isn't blowing head-on to the turbine, this mechanism turns the rotor accordingly.

**5 STEP-UP TRANSFORMER**
A step-up transformer is situated at the base of the turbine. This increases the electricity's voltage to reduce energy losses later in the cables.

## WIND ENERGY EMERGENCE

**The idea for a renewable energy wind turbine came from a Scottish engineer called James Blyth. In 1887, Blyth produced a turbine system in his own garden that could power the lights in his house on a windy day. At a time when the need for renewable energy was much less of a priority, his invention failed to become popular. Blyth's invention would later have its time to shine as a solution to the energy crisis in the 1970s. When it became apparent that fossil fuels would run out in the relatively near future, governments had to look elsewhere for alternative energy sources. Since this revelation, wind farms have increased in number and productivity, with scientists now predicting that by 2050, wind energy will produce one-third of the world's electricity.**



This was the design of James Blyth's wind turbine, which was used to power his home

© Alamy / Getty / Wiki: Tap London

# THE BUZZ ABOUT BEES

WORDS **AILSA HARVEY**

**Why different species of this pollinating insect are crucial in keeping our planet healthy**

**DID YOU KNOW?** You can save exhausted bees by feeding them a mix of half white sugar and half water

**Did you know?**

Bees can smell the footprints of other bees

Whenever you see a bee, most of the time it will look like it's on a mission. This mission usually involves collecting food for itself – and likely others in its hive – to survive on. What you may not be aware of is that this bee's mission is also a mission on your behalf. Every time a bee travels from one flower to another, it's carrying out pollination, spreading tiny grains of pollen between flowers and enabling the plants' life cycle to continue. This makes bees crucial creatures in maintaining biodiversity, as many plants would become extinct without outside help. Although they aren't the only pollinators on our planet, plant life without bees would be a lot more dull. Our diets would be much less nutritious if some natural foodstuffs were to cease to exist, while landscapes would lack colour, as bees pollinate 80 per cent of Europe's wildflowers.

Some bees live solitary lives, while others provide for massive colonies in their thousands. Together, these diverse bee communities consistently visit flowers in order to stock up their nests with large quantities of food. This makes them the most productive of all pollinators. There are around 20,000 different bee species, each with unique features and traits that help them access the sweet, sugary nectar of specific plants. Garden bumblebees have long tongues with which they can access deep-pitted flowers like honeysuckles, for example, while the early bumblebee is smaller and more nimble for navigating droopier flowers.

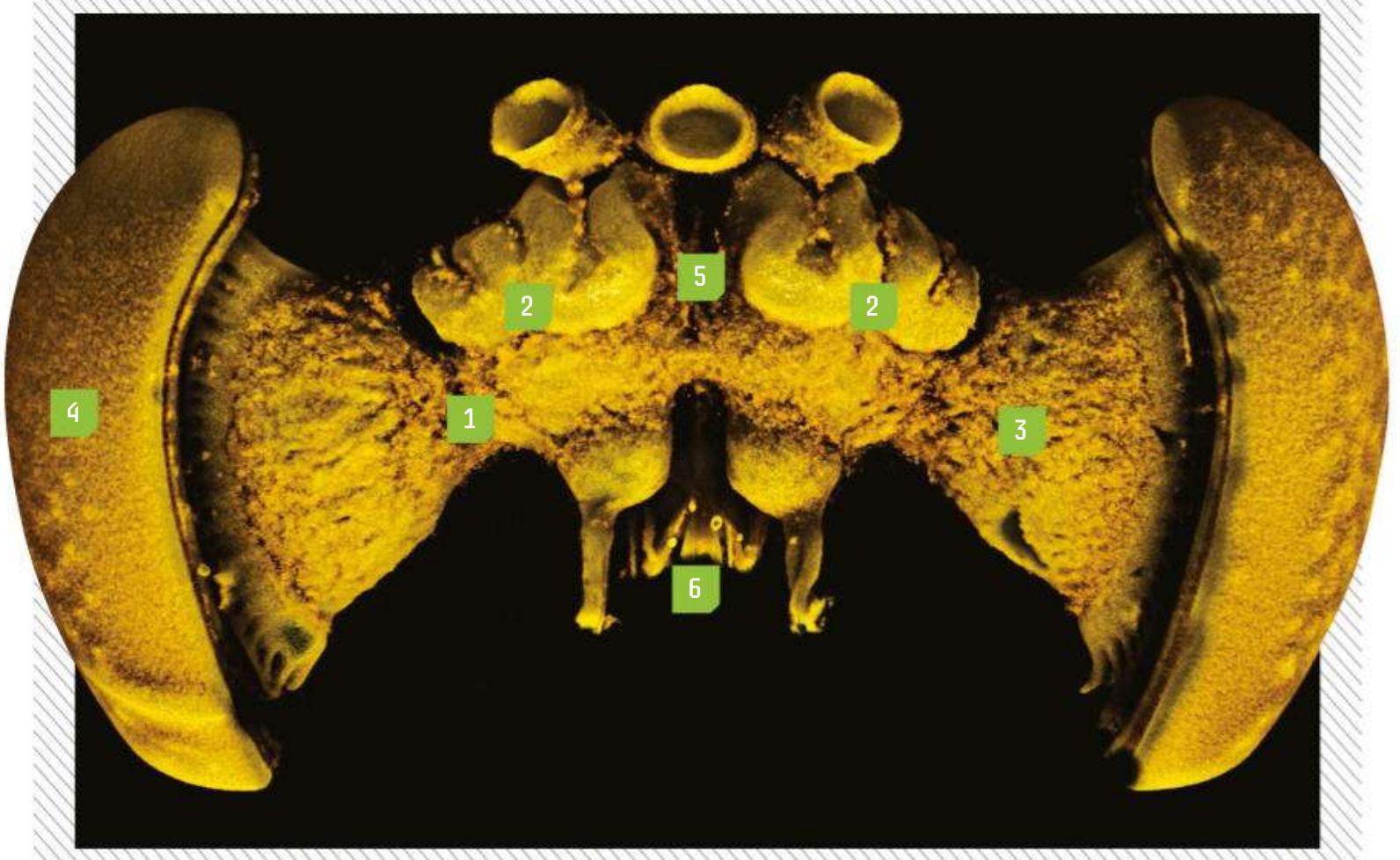
## BEE BRAIN

**How this tiny yet sophisticated insect organ works**

**1 PROTOCEREBRAL LOBE**
In this area, images from the bee's eyes send visual information to other areas of the brain to be processed.

**2 MUSHROOM BODIES**
These are the brain's learning structures, where memories are formed.

**3 LOBULA**
These outer areas analyse a larger area in the field of vision. It processes shapes and can recognise motion.




**4 MEDULLA**
Colour information is processed in the medulla.

**5 LATERAL HORN**
This area differentiates between the odours of pheromones – chemicals released by living things.

**6 POSTERIOR BRAIN**
The posterior brain is part of the central nervous system. The connected nerves mean the brain can control the body's movements.

## DIFFERENT PERSONALITIES

**Most honeybees are diligent workers, maintaining their hive, foraging and producing food for winter. Their work can appear almost robotic as they dedicate their time to benefit the hive, and their work ethic is the root of a popular term many people use to describe someone when they see them working hard – a 'busy bee'.**

**However, research shows that there is much more to an individual worker bee than its ability to provide for its hivemates. Scientists at the University of Illinois discovered that bees have unique personalities. In any hive, there are some bees who are more driven to adventure and others who are less willing to perform a certain act within a hive community. When a bigger hive is needed, only around five per cent of bees will actively search for a new home. These same bees are also more than three times as likely to search for food as the remaining bees. In their studies, the scientists learned that the higher the levels of the hormones dopamine and octopamine that a bee produces, the more likely they are to scout new hives.**

Around 60,000 worker bees care and provide for their queen

© Getty / Science Photo Library

Bumblebees have relatively bulky round bodies compared to other species

# THE WORLD'S AGRICULTURAL POLLINATORS

Bees are the best pollinators in the world, enabling most of the planet's plant life to grow and reproduce. To do so, the bees collect a powdery substance called pollen from the centre of a plant's flower as they land on it. This pollen contains the flower's male reproductive cells, which the bees carry to the next flower. By landing on an assortment of flowers, the bees combine the reproductive cells of male and female plants. This needs to occur for fruit to grow on the plant, containing seeds that can create a new generation.

Around one-third of the plants we eat rely on pollination by bees, especially by bumblebees. Some of the many foods that bumblebees pollinate include tomatoes, aubergines, peppers, blueberries, cranberries, melons, raspberries and strawberries. In addition, bumblebees are the only known pollinators of potatoes. This means that if we don't protect bumblebees, we could lose this staple vegetable.

## HONEYBEE ANATOMY

**How bees' bodies assist with plant pollination**

**5 HONEY STOMACH**
The nectar retrieved from plants is sucked in and accumulates in a specialised part of a bee's stomach, ready to be used for making honey in the hive.

**2 POLLEN BASKET**
Not all pollen is transferred to another plant. Some honeybees mix nectar with pollen to form large clumps on their back legs. This is taken to the hive as a protein-rich food.

**1 HAIRY LEGS**
As bees fly through the air, the fine hairs covering their bodies become statically charged. Pollen from a flower is then attracted to the hairs and attaches to the bee.

Teddy bear bees are between 15 and 20 millimetres in length

## TEDDY BEAR BEE

Australia has no native bumblebee species, so how does it keep pollination levels high? The answer comes in the form of some unique Australian bee species, such as the teddy bear bee. This mortar bee – a group of bees named for their tendency to dig holes in the mortar between buildings' brickwork – is often mistaken for a bumblebee. But if you look closely, its plump body and wide eyes make it relatively easy to single out.

To appropriately match their cute nickname, teddy bear bees are stingless. They flaunt golden-brown hair and have dark bands across their backs. The type of pollination these bees carry out is called buzz pollination. This involves the bees holding onto the flower and shaking their flight muscles, causing a plant to release its pollen from small capsules. Teddy bear bees then carry this pollen to crops like tomatoes, blueberries and chillies.

**DID YOU KNOW?** Bees can recognise images of human faces

**4 TUBE-LIKE TONGUE**
Their tongues, called proboscises, can reach far into a flower to retrieve nectar. This sugary substance attracts the bees to flowers.

**3 GRIPPY FEET**
At the end of their legs, bees have claws that help them grip onto the surfaces of plants.

1

3

4

This image shows the world's largest bee's size in comparison to a human hand.

*Perdita minima* weighs just one-third of a gram

## 5 WAYS BEES TALK

**1 PHEROMONES**
When a bee colony is under attack, bees release 'alarm pheromones'. These are chemical hormones that are released outside the body, initiating a social response in others, such as to flee or defend a hive.

**2 TOUCH**
Bees will touch each other's antennae to tell each other apart. These are their most touch-sensitive areas.

**3 DANCE**
During a dance called the 'waggle dance', honeybees move in zig-zags while shaking their bodies. This secret code tells other bees the distance and direction of food sources.

**4 SOUND SIGNALS**
Bees make different buzzing noises and frequencies depending on what they wish to convey. For example, when a queen bee first emerges from her cell, she will release short pulse vibrations.

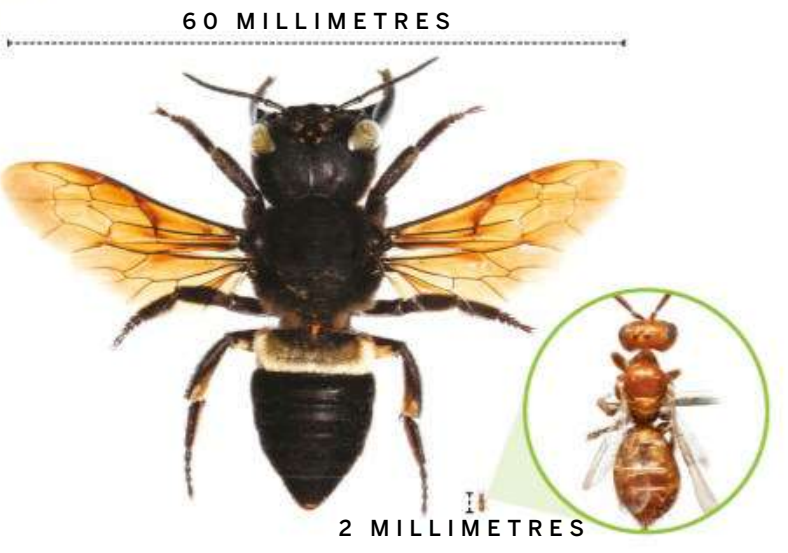
**5 SCREAM**
When under attack, bees can scream with their bodies. They point their abdomens up and run with their wings vibrating. The result is compared to the sound of a human scream.

**Did you know?**
Australia has 1,600 native bee species

## BIGGEST AND SMALLEST SPECIES

**The bulkiest and tiniest bee species have a difference in length of about 38 millimetres. The former is Wallace's giant bee (*Megachile pluto*), which earns the title of the largest bee in the world. This hefty Indonesian bee was discovered by scientist Alfred Russel Wallace in 1858 and is four times the size of a European honeybee, with a wingspan over six centimetres. After this amazing discovery, a bee from this species wasn't spotted again until 1981. In the time between sightings, it was falsely presumed to be extinct. At the other end of the scale, at less than two millimetres in size, *Perdita minima* is the world's smallest known bee. They construct tiny solitary nests in the desert sands of the southwestern US. When studying these bees, scientists have to look for their shadows on the ground, as the bees themselves are difficult to spot. Their comparatively strong wings and long leg hairs are adapted to carry large volumes of pollen compared to their small bodies.**

## ACTUAL SIZE COMPARISON




© Alamy / Getty / Wiki: KRHick

# HIVES AND HOMES

From solitary bees to crowded colonies, here are the locations bees call home

**2 HONEYBEE HOLLOWS**
Honeybees nest in the hollow centres of trees. In these hives there are between 20,000 and 60,000 female worker bees.

**4 LEAF LODGINGS**
In the stems of plants or cavities in old wood, leafcutter bees manufacture their nests. To make individual cells inside these structures, the bees cut pieces out of leaves and glue them together with their saliva.

**5 MUD-SEALING MASONS**
Mason bees will choose any naturally occurring gap – typically around 15 centimetres deep – to call their home. This includes the holes that form in tree stumps or old buildings. By the beginning of summer, these bees will have sealed the entrance to their homes with mud.

**6 UNDERGROUND NETWORKS**
The miner bee is a solitary bee that digs into the soil to construct tunnel systems for nesting. Miner bees may make nests close together, but a female bee will only provide for their own offspring.

**DID YOU KNOW?** Wallace's giant bee scrapes resin off trees to build nests with

## Did you know?

There are at least 2 trillion bees in the world

# BEE INTERACTIONS

**7 GUARDED TERRITORY**
At the entrances into some of Australia's hollow trees, four or five sugarbag bees can sometimes be seen lingering. These are sugarbag bee guards whose job it is to defend the spiral-shaped hive inside.

**3 TWIG TUNNELS**
Carpenter bees carve tunnels into wooden structures such as logs and twigs. By leaving the natural shape of the wood, the presence of their nests isn't obvious – except for a small pile of wood carvings.

**1 BORROWED BURROWS**
Bumblebees will utilise ready-made cavities such as old rodent dens. Shaded areas are usually chosen to prevent the nest overheating.

**1 POLLEN THEFT**
When pollen is scarce, honeybees have been known to take part in theft. This involves attacking other bee species and taking pollen from their pollen baskets rather than from flowers.

**2 NEST PARASITES**
These bees take nectar from flowers, but this is for their own personal energy rather than to return to a nest. This is because these parasitic bees lay their eggs in other bees' nests. The males release a scent near other bees' nests for females to follow.

**3 ROYAL DEATHS**
If more than one queen bee emerges in a honeybee hive, the two queens must fight each other to the death. When the first queen bee is born, it needs to kill the other hatched and unhatched queen bee cells as there can only be one queen.

**4 DO NOT DISTURB**
When female leafcutter bees are building nests and collecting pollen, they don't want to be disturbed. Male leafcutter bees, on the other hand, will often be looking for a mate. As a signal for males to stay away and to avoid knocking the collected pollen over, the females point their pollen-covered bellies up into the air.

**5 STINGLESS BEE FIGHTS**
Stingless *Trigona carbonaria* and *Tetragonula hockingsi* will attack each other's nests. In these invasions, the surviving worker bees of the previously settled colony may become worker bees for the invading species.

© Alamy / Getty / Wiki: Jeans Photos / Illustration by Nicholas Forder

# THE SCIENCE OF SINKHOLES

Sinkholes can be dangerous

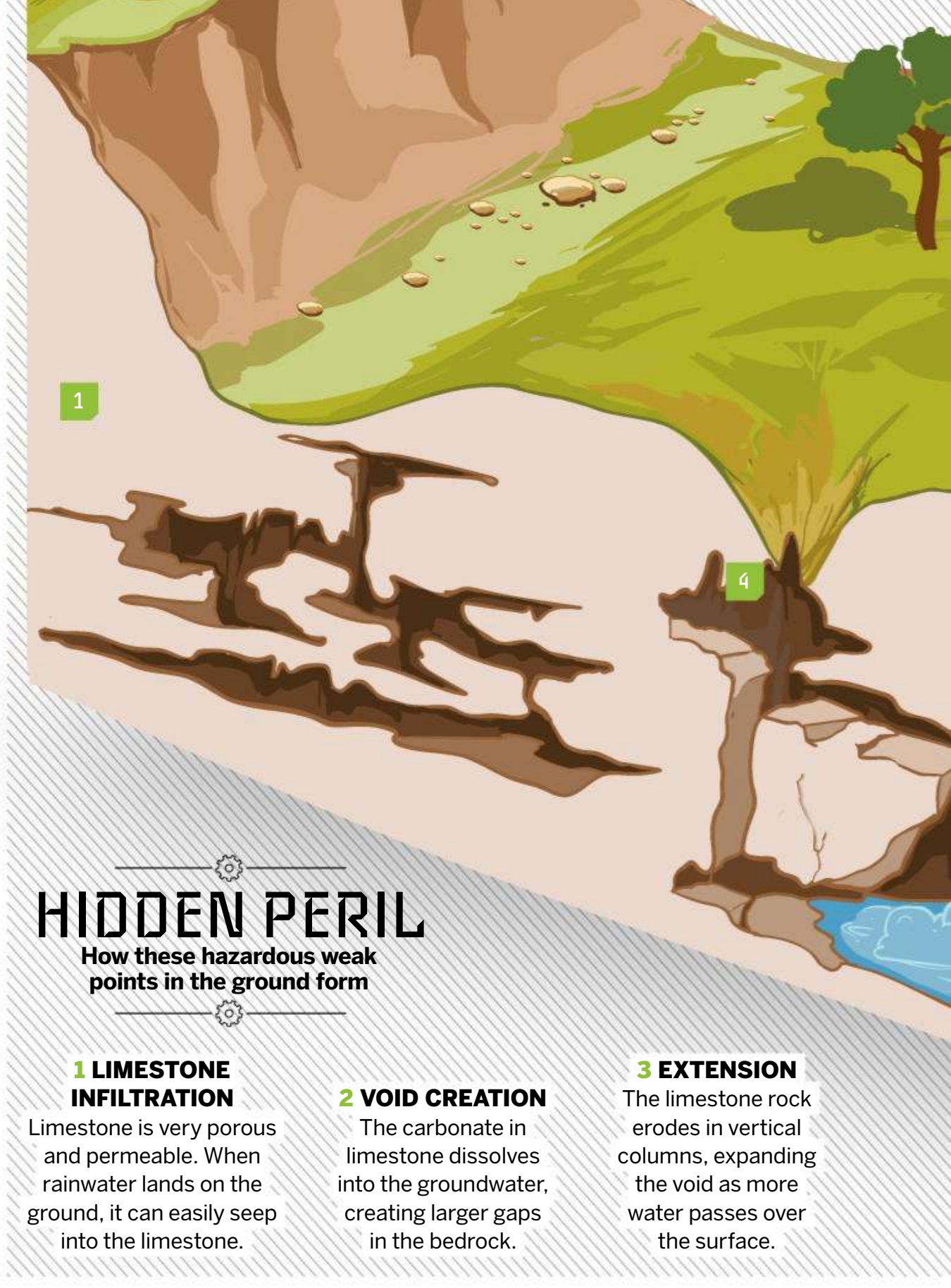
## Why holes sometimes open up in the ground and swallow the land above

WORDS **AILSA HARVEY**

Although the chances are relatively low, it's possible for the ground to open up and swallow everything that once lay above it. These events occur due to voids in bedrock. When significant space forms underground, the land can't support itself, and it collapses to form depressions known as sinkholes. 20 per cent of the US' land is susceptible to these areas of sunken ground. Not all sinkholes engulf communities with no warning, however. Most of them are less disguised. Instead of incaving unexpectedly, some sink slowly and visibly over time as groundwater dissolves the rock below. This can happen when there is nowhere for water to drain, so it slowly seeps into pores in the soil and rock. Areas that are covered with soluble rock, such as salt beds, limestone and other carbonate rocks, are more likely to develop sinkholes.

Some sinkholes aren't the result of Earth's natural drainage processes. Many of them appear in urban areas where there is limited space that hasn't been built on. This causes rainwater to congregate in the same drainage areas, making the distribution of groundwater uneven. What's more, when the bedrock does become weak, the presence of multistorey buildings and extensive road systems adds weight that puts the land under pressure.

A huge sinkhole blocking the road




### HIDDEN PERIL

**How these hazardous weak points in the ground form**

**1 LIMESTONE INFILTRATION**
Limestone is very porous and permeable. When rainwater lands on the ground, it can easily seep into the limestone.

**2 VOID CREATION**
The carbonate in limestone dissolves into the groundwater, creating larger gaps in the bedrock.

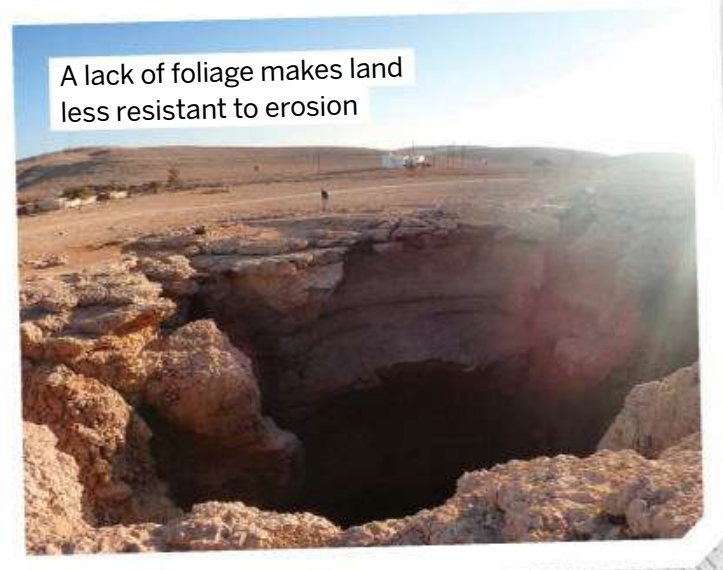
**3 EXTENSION**
The limestone rock erodes in vertical columns, expanding the void as more water passes over the surface.

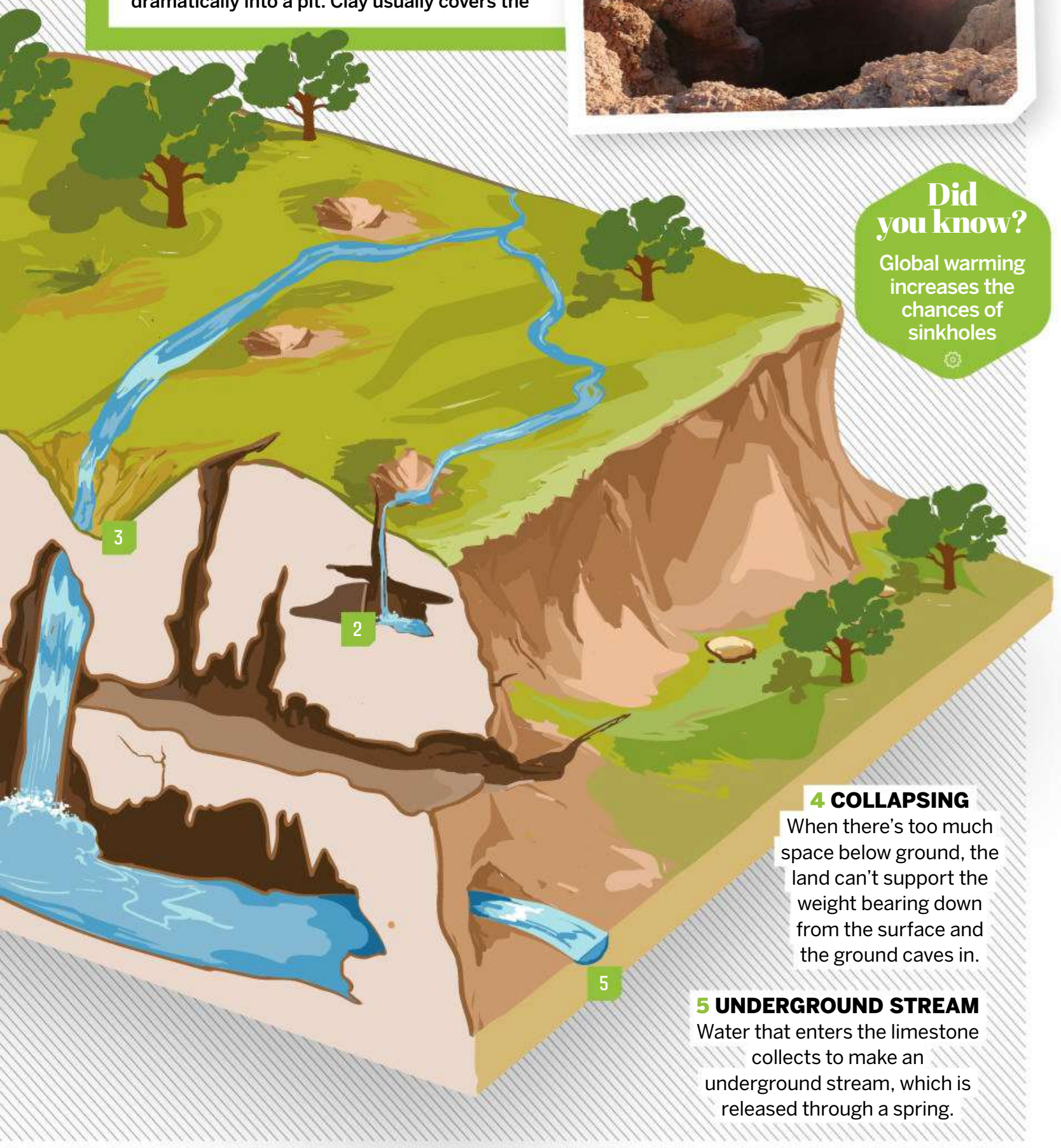
**DID YOU KNOW?** The deepest sinkhole in the world is the Xiaozhai Heavenly Pit in China at over 660 metres deep

## NATURALLY OCCURRING

There are three types of natural sinkholes: dissolution, cover-subsidence and cover-collapse sinkholes. Dissolution sinkholes occur due to a lack of soil and vegetation covering the bedrock. Water seeps straight into the bedrock, slowly dissolving it over time to form a sinkhole. Cover-subsidence sinkholes are found in areas where sand covers the bedrock. The small sand grains fall into gaps in the bedrock, causing a dip in the surface. Because the sediment still takes up some space, this type of sinkhole is smaller in size.

Cover-collapse sinkholes are the best known and most dangerous. This type of natural sinkhole has a strong ground layer that supports everything above it for longer, but this eventually leads to land falling more dramatically into a pit. Clay usually covers the bedrock in cover-collapse sinkholes. As a void forms below ground, the clay arches to make a thin yet relatively sturdy upper layer, concealing the death trap. At any point these can buckle under the weight pushing down on them, and in some cases the presence of the sinkhole is unknown until it's too late.


A lack of foliage makes land less resistant to erosion




**Did you know?**

Global warming increases the chances of sinkholes

**4 COLLAPSING**
When there's too much space below ground, the land can't support the weight bearing down from the surface and the ground caves in.

**5 UNDERGROUND STREAM**
Water that enters the limestone collects to make an underground stream, which is released through a spring.

## 5 FACTS SUDDEN COLLAPSES

**1 GUATEMALA CITY, GUATEMALA**
An underground pipe burst, creating an unstable cavity. As the surrounding ground consisted of porous volcanic pumice, an 18-metre-wide and 100-metre-deep sinkhole formed.

**2 CERRO SARISARIÑAMA, VENEZUELA**
Jaua-Sarisariñama National Park is home to four mountaintop sinkholes. These are all about 350 metres deep and wide. They even have their own forests growing inside of them.

**3 THE QATTARA DEPRESSION, EGYPT**
Measuring 80,000 metres long, 120,000 metres wide and 133 metres deep, this is the largest natural sinkhole on Earth. It was caused as salt in the soil eroded the rock into a fine and unstable sand.

**4 THE DEVIL'S SINKHOLE, TEXAS**
This sinkhole is 18 metres wide and 106 metres deep. Over 3 million bats use this grand cavity as their home.

**5 DAISETTA, TEXAS**
In May 2008, the ground below the town of Daisetta caved in to create a hole 45 metres deep and 180 metres wide. After swallowing everything in its path, the sinkhole filled with water from nearby swamps to become a large lake.

© Getty / Alamy / USGS

# WHAT IS FROGSPAWN?

## Discover the origins of your favourite garden amphibians

WORDS **SCOTT DUTFIELD**

Near the start of the year, ponds and streams host clusters of gelatinous eggs from their frog inhabitants. All amphibians in freshwater sources lay these jelly-like eggs, known as spawn, after mating season. Newts lay individual eggs bundled up in underwater leaves, salamanders find cracks and crevices in subterranean rocks and tropical poison frogs find moist leaves to deposit their eggs upon.

The frogspawn you're likely to find in your garden pond belongs to either the common frog (*Rana temporaria*) or the northern pool frog (*Pelophylax lessonae*). Following a winter of hibernation, these frogs emerge in spring ready to reproduce. Males attract mates by serenading them at night with loud croaks. Once a successful pair has mated, a female lays rafts of thousands of fertilised eggs into the water.

Frogs prefer to lay their spawn in shallow water, like vegetation field pools, ponds and even buckets. Vegetation acts as an anchor for the cluster of eggs and prevents them from drifting away. In the first four weeks, embryos in the spawn will grow and hatch as tiny tadpoles, and over the course of several months will metamorphose into froglets. Typically, only one in 50 eggs will survive long enough to become an adult frog; the remainder will likely make snacks for predators such as birds, fish, dragonfly larvae and even snakes.

A dark developing embryo sits at the centre of each egg

**Did you know?**

During mating, frogs stay attached to each other for up to 24 hours

## FROM FERTILISATION TO FULLY GROWN

**How these amphibians spend the first few years of life**

**1 EGG LAYING**
Between January and March, female frogs will lay their eggs in clusters underwater.

**2 BIG BROOD**
A single female common frog can lay up to 4,000 eggs at a time.

**3 EGG PROTECTION**
The frog embryo is surrounded by a gelatinous capsule that helps it float.

**4 TADPOLES**
At around three weeks, tadpoles emerge from their jelly capsules and start feeding.

**5 FROGLETS**
After 16 weeks, tadpoles lose their external gills, the tail is gone and legs emerge.

**6 ADULTHOOD**
Froglets reach maturity at around two years old, and will then find a mate of their own.

### FROGSPAWN VERSUS TOADSPAWN

**Frogs and toads belong to the order of amphibians called Anura, meaning 'without a tail'. Among the order there are 5,000 species of frogs, including all the lumpy-skinned toads of the world. While all toads are frogs, not all frogs are toads. Although the two look alike, frogs and toads have very different spawn. A frog's spawn is typically a cluster of eggs, whereas toadspawn forms long chains, like beads on a string. Strings of toad eggs are often found draped over underwater plants, but are laid a little later in the spring compared to frogspawn. Toad tadpoles look almost identical to frog tadpoles and are only differentiated by a shorter tail and bigger head.**

An example of frogspawn (left) and toadspawn (right)

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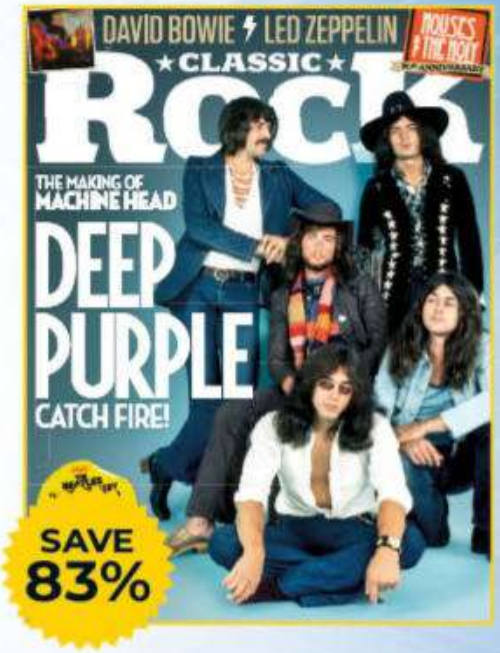

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**DID YOU KNOW?** Viking women were free to own property and request a divorce

# VIKING RAIDERS

## Portrayed as bloodthirsty pirates pillaging innocent villagers, Vikings also ruled the waves with a lucrative trade network

WORDS **FRANCES WHITE**

The great white sail cracked as the vicious Atlantic wind lashed against it, but still the ship sailed on. Long and sleek, the warship, crafted from mighty oak, crashed through the waves, sending a sharp spray of water across the deck. The men inside rowed as one, their mighty muscles straining as they plunged the oars deep into the water and drove the ship forward through the turbulent waves. Their strength alone brought the ship to land and they poured out onto the beach. Dressed in thick woollen tunics, the warriors were armed with an array of weapons, from long, sharpened spears to hefty battle-axes. With a booming voice one man yelled to the others, thrusting his sword into the air, and the rest bellowed in response. Then onward he ran, as the united force thundered uphill against the billowing wind. Their destination? A coastal monastery bursting full of gold, gems and hefty food supplies ripe for the taking, and only a collection of quiet, unassuming monks to protect it.

This image of monstrous invaders laying siege to innocent monasteries and pillaging them of their precious items is the first one that leaps to mind when many are confronted with the word 'Viking'. The portrayal of the Norse tribesmen as thieves and pillagers is so prevailing that it's often forgotten that the word Viking itself means to go on an expedition. It's easy to fall into the assumption that these people were nothing more than pirates – taking from those too weak to defend themselves. And it is undeniable that this happened: the Viking invaders sailed from Scandinavia to the coasts of the British Isles and beyond, invading villages and monasteries, killing the inhabitants and stealing their riches. It's spoken about in first-hand accounts and it's still being evidenced today in the reams of Viking hoards discovered from anxious townsfolk who hurried to hide their riches from the merciless invaders.

**Did you know?**

**Vikings had excellent hygiene, bathing at least once a week**

However, this only tells half the story. Two things powered the Viking civilisation: the vicious raids they're famous for, and something else – trade. Not only did Vikings set up new colonies in the lands they invaded, but they also created powerful trade routes that helped their nation become one of the most prosperous in the world.

For the majority of the year, the same Vikings who had pillaged the towns worked the land, tirelessly toiling in the field or creating intricate and valuable ornaments and jewellery to fund their blossoming civilisation.

# VIKING VOYAGES

## The Vikings were able to voyage further and wider than any civilisation before

Centuries before Christopher Columbus would stumble upon the land now known as America, the Vikings had claimed the Atlantic Ocean as their own backyard. They had mastered Russia's river system and reached the Middle East; their impressive voyages helped them become leaders of a rapidly developing world, and this new Viking civilisation thrived on the power of a single creation: the ship.

The entire Viking society was built around their ships, which were bigger, lighter and faster than any before. These vessels had been perfected over many years with the power to brave the vicious storms of the Atlantic Ocean, but also the sleek construction to skim through shallow rivers. These powerful and efficient ships enabled their mighty passengers to create colonies across the world, and the building and maintaining of these vessels became the basis of Viking society.

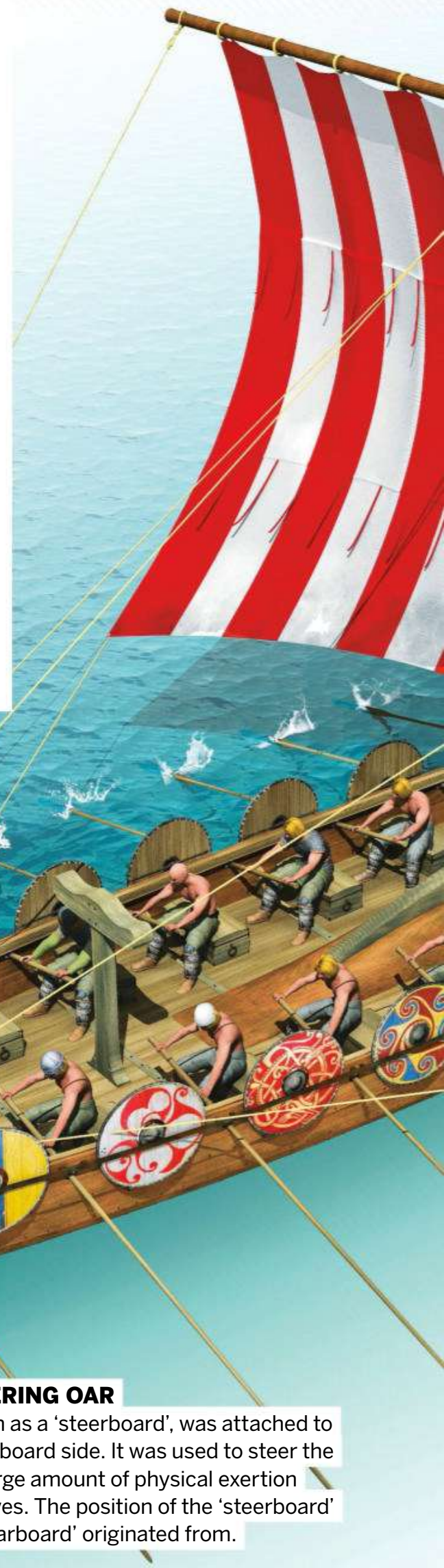
Vikings were using their mighty sea power to trade around the coast of Europe while the British Empire was merely a collection of scattered kingdoms unable to defend their shores. Viking sailors were aware that it was often easier to take the same journey by water rather than land, with some journeys taking five days by sea compared to a month on land, and they used this to their advantage. Longer voyages were carried out by those settling in strange and exciting foreign lands, and the Viking civilisation spread to Iceland, Greenland and even to Canada and North America.

The image of a Viking longboat crashing through the waves with its fierce dragon figurehead and its long, sleek curves is certainly an inspiring one, but for those onboard, life was not quite so glamorous. With no shelter, at night the sailors used the sail as a makeshift tent that they would sleep under, shivering beneath blankets or animal-skin sleeping bags. The only sustenance would be dried or salted meat with water, beer or sour milk to drink. The sinking of vessels was no great tragedy, but rather expected on long journeys. There would be no rescue sent, as usually nobody knew about sunken ships for weeks, months or even years. It was not unusual for any number of ships to go missing on voyages across the brutal Atlantic Ocean. When Erik the Red travelled to Greenland, only 14 of his original 25 ships managed to arrive safely.

However, it was the determination and hardiness of the voyagers willing to take these risks that led the Vikings to valuable and exotic treasures and trade lying along the coastlines of the world. Towards the end of the 8th century, Viking voyagers began an invasion of England that would forever determine the fate of the island nation. By 860 CE this pioneering spirit led them to the assault of Constantinople. Some 20 years later in 885, Viking ships attacked the mighty city of Paris. Driven by the quest for trade, territory, plunder and a thirst for adventure, the impact of these historic voyages can still be felt around the world today.

**Did you know?**

The Vikings had a god of skiing and snow sports called Ullr



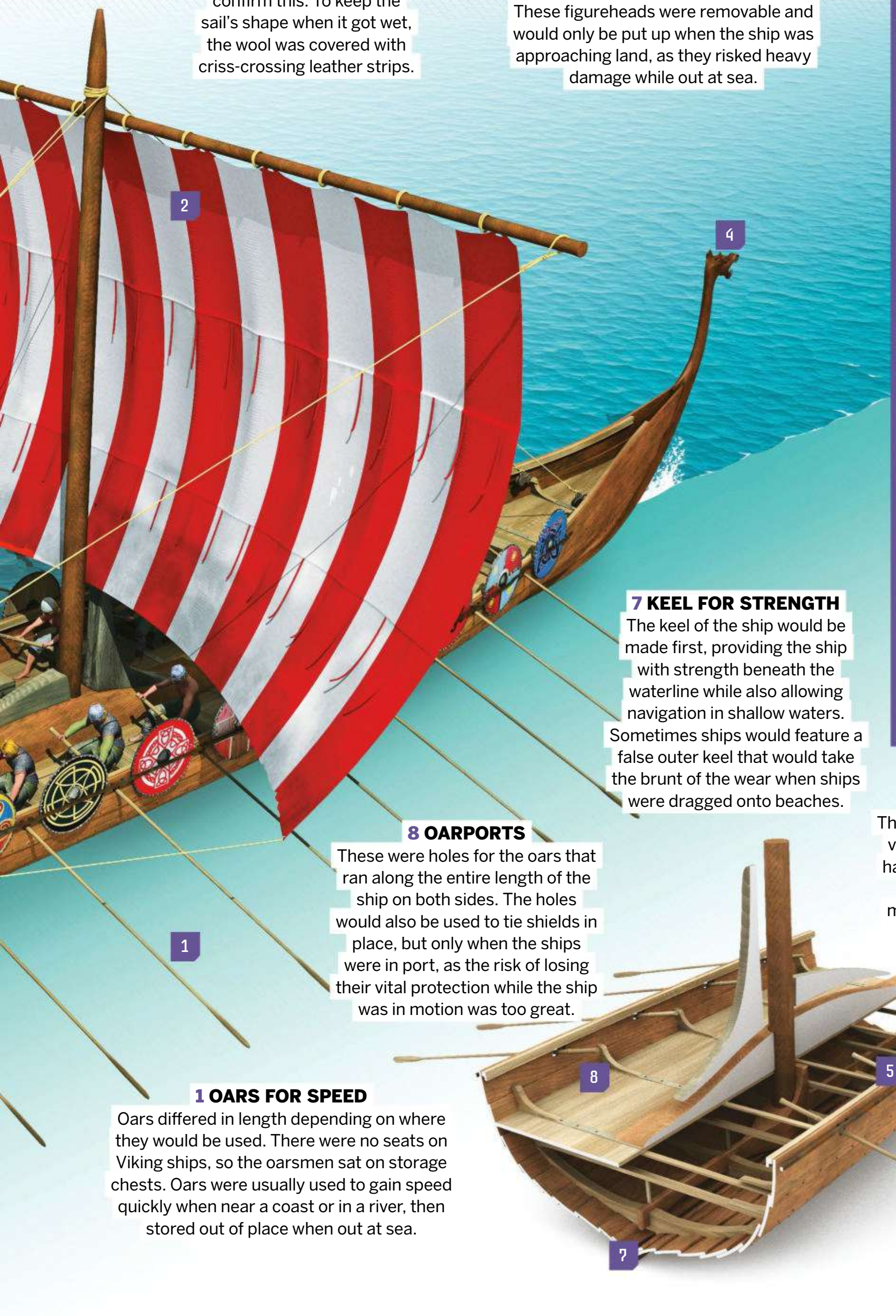
**3 WOODEN HULL**
All Viking ships were made in the same way – using planks of oak or pine overlapped and nailed together. The ships were then reinforced and made watertight by using tarred wool or other animal furs to fill in the gaps between the planks.

**6 STEERING OAR**
This rudder-like oar, also known as a 'steerboard', was attached to the back of the ship on the starboard side. It was used to steer the ship and would require a large amount of physical exertion compared to modern alternatives. The position of the 'steerboard' is where the term 'starboard' originated from.

**DID YOU KNOW?** The Vikings captured and sold humans

**2 WOOLLEN SAIL**
Longships featured one large, square sail approximately ten metres wide. These were most likely made from wool, though no sails have survived to confirm this. To keep the sail's shape when it got wet, the wool was covered with criss-crossing leather strips.

**4 FRIGHTENING FIGUREHEAD**
The front of the ship was often decorated with a carving of an animal head, usually a mix between a dragon and a snake. These figureheads were removable and would only be put up when the ship was approaching land, as they risked heavy damage while out at sea.




## NAVIGATION

**Before some of the greatest explorers in history were born, Vikings had already navigated their way around the world. But with no compasses, satellites or radios, how did these tribes of Scandinavians manage to map the globe so impressively? The answer is simpler than you might expect – experience. Rather than relying on devices, Viking travellers trusted nature to guide them. They would study the positions of the stars and Sun, and even the colour of the sea and movement of the waves would give them an indication of how close they were to land. Once a journey was complete, sailors would recount their voyage to others who wished to make the same journey. This ancient wisdom would be passed through generations.**

**The only tools Viking sailors needed were related to the Sun. For example, a Sun-shadow board would be used at noon to check whether the ship was on course. A sunstone could also be used on foggy days when the Sun was not visible. This stone would change colour to indicate the position of the Sun behind the clouds.**

Iceland spar, also known as optical calcite, was used as a sunstone

**7 KEEL FOR STRENGTH**
The keel of the ship would be made first, providing the ship with strength beneath the waterline while also allowing navigation in shallow waters. Sometimes ships would feature a false outer keel that would take the brunt of the wear when ships were dragged onto beaches.

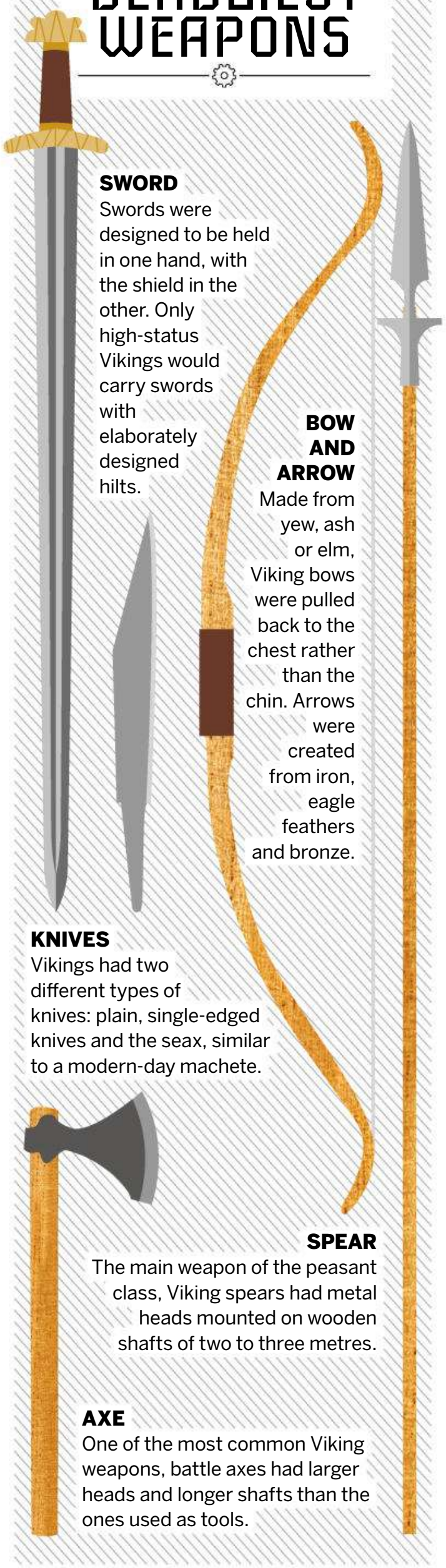
**5 SMALL HOLD**
The longship was designed for war, so it was vital for it to be fast. Because of this, they had a small loading capacity, with room for only high-value goods and booty. The merchant ships would be able to carry far more cargo, with room for livestock.

**8 OARPORTS**
These were holes for the oars that ran along the entire length of the ship on both sides. The holes would also be used to tie shields in place, but only when the ships were in port, as the risk of losing their vital protection while the ship was in motion was too great.

**1 OARS FOR SPEED**
Oars differed in length depending on where they would be used. There were no seats on Viking ships, so the oarsmen sat on storage chests. Oars were usually used to gain speed quickly when near a coast or in a river, then stored out of place when out at sea.

© Science Photo Library

## DEADLIEST WEAPONS



**SWORD**
Swords were designed to be held in one hand, with the shield in the other. Only high-status Vikings would carry swords with elaborately designed hilts.

**BOW AND ARROW**
Made from yew, ash or elm, Viking bows were pulled back to the chest rather than the chin. Arrows were created from iron, eagle feathers and bronze.

**KNIVES**
Vikings had two different types of knives: plain, single-edged knives and the seax, similar to a modern-day machete.

**SPEAR**
The main weapon of the peasant class, Viking spears had metal heads mounted on wooden shafts of two to three metres.

**AXE**
One of the most common Viking weapons, battle axes had larger heads and longer shafts than the ones used as tools.

A dramatic Viking raid on the English coast

# RAIDS

## No monastery was safe from the fiery scourge that swept over the land from beyond the sea

They had arrived in the dead of night; the darkness had been so thick that the monks had not seen their ship until it landed on the shore, when it was too late to call for help. A brother had run into the halls, waking the monks from their beds with shrill cries of: "The demons are here! They're coming! They're coming!" Some of the brothers began to scream for help, while others leapt into action, grabbing precious items and concealing them in the folds of their cloaks. But already the doors were down, and already the invaders were here. They were huge – bigger than any man the humble brethren had ever seen – with their wild blonde hair and mighty weapons grasped in hand. They leapt upon the monks immediately, hacking at their bodies with a frenzied ferocity. Some pleaded for mercy, while others did not have time to plead. There was no time for negotiations, and how can you negotiate with pure, unbridled violence? There was only death, destruction and blood as they swung their axes and jabbed their swords. One brother alone had managed to escape the massacre. He speedily weaved through the figures and threw himself down into the tall grass outside. He watched as body after body was thrown from the doors of his home. He watched as men still alive were cast off the high cliff into the sea, and he watched as the heathens set the holy walls alight with flame. The hot wind lashed against his face and robes in the flickering darkness. He grasped a golden chalice in his hands numbly – the only thing he had been able to rescue before fleeing. The invaders had the rest of it, all the precious items loaded into sacks on their large ships. And almost as quickly as they had arrived, they slipped away from the shore and returned to the darkness.

In 793, a Viking crew sailing near northeast England raided a Christian monastery at Lindisfarne. For the Vikings the strange, exposed building packed full of valuable treasures was an opportunity too good to miss, but for many in England this shocking and unprovoked attack marked the beginning of the scourge of Viking raids. These sporadic but violent assaults continued across the coasts of England, and by 855 a force known as the Great Heathen Army had arrived in East Anglia. The army made its way across the country, capturing cities as it went, overrunning and overpowering the land.

**Did you know?**
Viking men would bleach their hair and beards blonde

The Scandinavian warriors also launched invasions across the coasts of Ireland and all over mainland Europe. These raids even stretched to the Baltic Sea and Persia. The initial reasons for such rapid expansion are hotly contested between historians, with some believing the raids were a brutal response to the spread of Christianity. Others believe that the Scandinavian population grew too large for its land, or perhaps they were the actions of men simply drawn by the thrill of adventure. Whatever the reasons, the invasions left a lasting scar on those who lived to see them.

**DID YOU KNOW?** Some Vikings were buried in boats surrounded by weapons, valuable property and slaves

# ANATOMY OF A VIKING WARRIOR

**1 HELMET**
Vikings didn't have horned helmets. They were round with a guard around the eyes and nose. There's only one complete Viking helmet left in existence.

**2 HAIR**
Long hair was favoured by both men and women. It would also be acceptable to shave one's hair or to wear it rolled in a tight bun near the nape of the neck. Men would also carefully groom their moustaches and beards.

**3 ARMOUR**
Mail shirts or metal armour would have been very expensive for the average raider, as would leather, so these were reserved only for those of high status.

**4 SHOES**
Shoes were most often made from one long piece of leather sewn to the shape of the wearer's foot. Straps would be used to secure the boot to the foot, and thick woollen socks were worn.

**5 SHIELD**
Round shields were common, made from light wood such as fir or poplar, and were reinforced with leather or iron around the edge.

# 5 STEPS TO MAKING A VIKING RAID

**1 PREPARATION**
They didn't strike haphazardly; instead raids were planned down to the finest detail. They would first identify a weak target to attack along the coasts. Because they had the fastest ships in the world they would launch their attack without any prior warning, ensuring that no help could reach their targets in time.

**2 GATHER HORSES**
Viking ships were designed to row upriver, but if the target was some distance away they would leave their ships and travel by horse. With no horses on the ships, they would raid nearby villages for available mounts. These would be used to transport them and their booty across the land.

**3 SURPRISE ATTACK**
The pious and humble monks didn't stand a chance faced with their fierce opponents armed with superior weapons. The well-trained Vikings would launch a sudden vicious attack on the monastery, slaying the holy men. Some would be stripped naked and cast outside, some taken prisoner and others thrown into the sea.

**4 LOOT AND BURN**
Once the monks were dealt with, Vikings ravaged and pillaged everything they could. They plundered valuables, including storages of food, but especially precious relics. But they often ignored the incredibly valuable bibles. Once they had looted the buildings they set fire to the monasteries and the villages surrounding them.

**5 ESCAPE**
Laden down with their prisoners and treasures, the Vikings would ride back to their ships, load them and sail away. They would later sell the gold, jewels and sacred emblems, and the monks would also fetch a high price in the European and Middle Eastern slave markets.

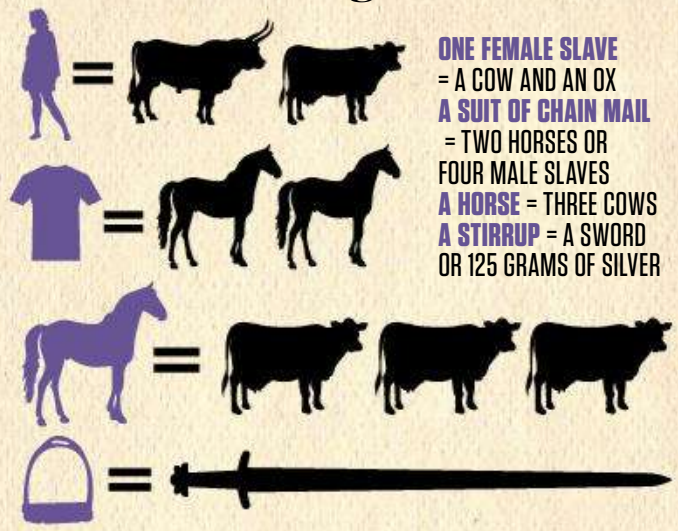
## THE ATTACK ON LINDISFARNE

**Lindisfarne is a holy island off the northeast coast of England. In 793 a Viking raid on the monastery of Lindisfarne sent a wave of dismay over Christians worldwide. Viking raiders invaded the monastery and "destroyed God's church on Lindisfarne with plunder and slaughter". Although the attack wasn't the first in the country, it was unusual in that it attacked the heart of the Christian nation in the north. A contemporary scholar wrote of the attack: "Never before has such terror appeared in Britain as we have now suffered from a pagan race. The heathens poured out the blood of saints around the altar, and trampled on the bodies of saints in the temple of God like dung in the streets."**

Irish monks first settled at Lindisfarne in 635 CE

© Getty

## What were the goods worth?



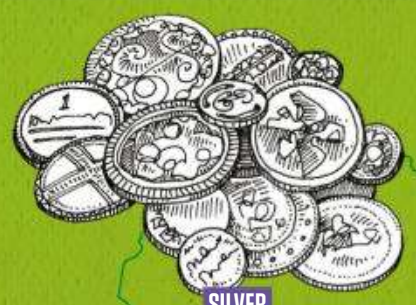
**ONE FEMALE SLAVE** = A COW AND AN OX
**A SUIT OF CHAIN MAIL** = TWO HORSES OR FOUR MALE SLAVES
**A HORSE** = THREE COWS
**A STIRRUP** = A SWORD OR 125 GRAMS OF SILVER

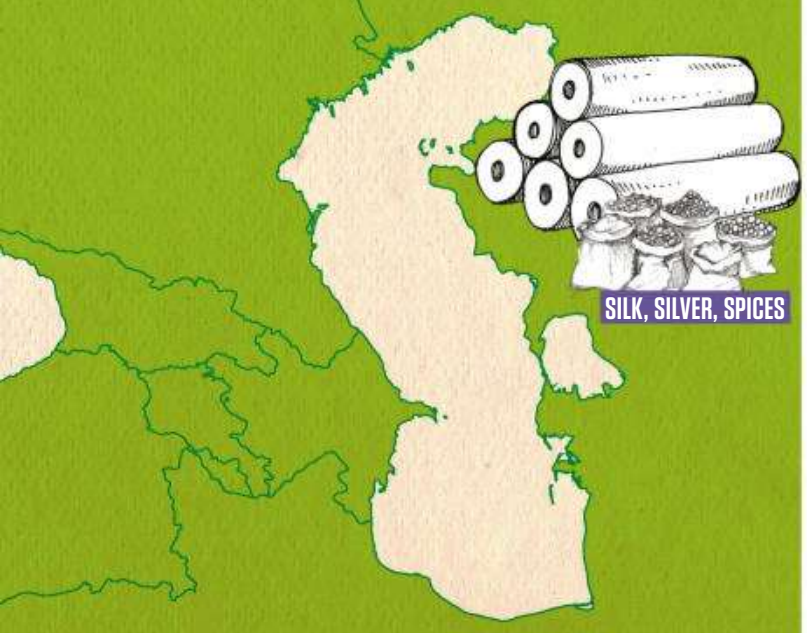
**DID YOU KNOW?** Vikings typically ate two meals a day, one in the morning and the other in the evening

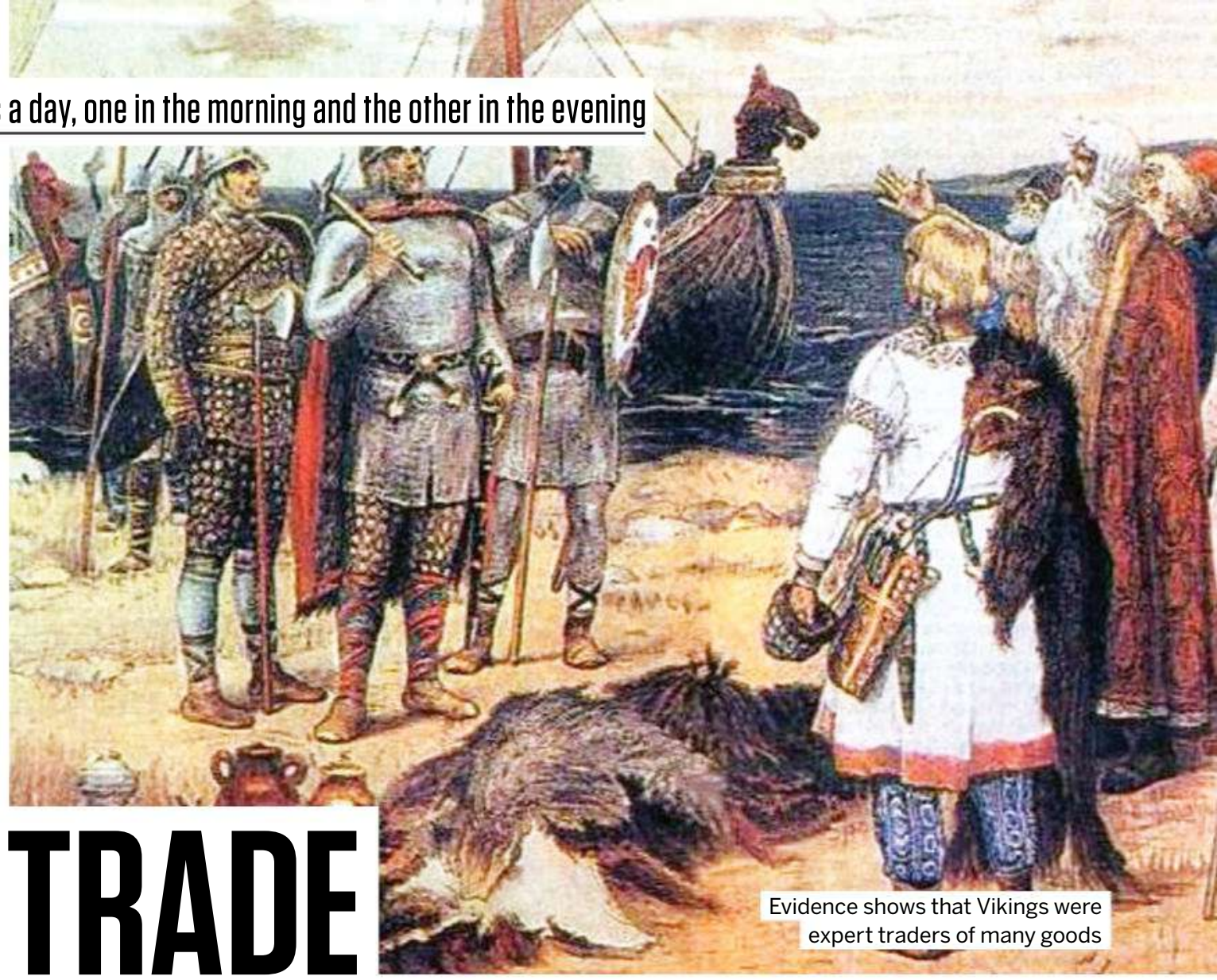
## RAIDERS OR TRADERS?

Stuart Perry manages a team of Viking interactives at Jorvik Viking Centre and archaeology and history interpreters across the group's five attractions

**What was the motivation behind the Viking invasions? Were they simply bloodthirsty raiders, or did they have more civilised aims?**
The Vikings, or Norsemen, were searching for land. Scandinavia is not rich in arable land – there is simply too much water and too many mountainous regions to support a population over a certain size. The Vikings had been raiding the coast of England since 793 and would've had plenty of opportunity to see the abundance of farmland, healthy crops and fat cattle all over the country. Combine this with the riches presented in the monasteries and towns they were so fond of raiding and England became a perfect area for expansion. As for being 'bloodthirsty raiders', there is that element to the culture, yes, but it was not simply for violence that the Vikings went raiding... it was for profit.



Evidence shows that Vikings were expert traders of many goods

# TRADE

## Vikings were powered by a complex and prosperous trade network

Although raiding and pillaging provided a quick intake of wealth, it wasn't a stable way to live or to build a civilisation. Instead the Vikings dedicated far more of their time to building up a prosperous and powerful trading network. Because of their superior ship-building skills they were able to travel to trade in faraway lands, obtaining a host of exotic and valuable goods. Their specially designed trading ships were able to carry up to 35 tonnes of cargo, including silver and livestock.

Trading markets began to emerge along the west Baltic Sea in the mid-8th century, where people came from far and wide to trade an array of goods. As these markets flourished, traders decided to settle permanently along the routes, transforming them into trading towns. Birka in Sweden, Kaupang in Norway and Hedeby in Denmark all grew to be prosperous and bustling trading settlements, with the inhabitants all working as craftsmen and merchants. Prosperous trading routes also emerged along the British Isles, with York and Dublin developing into major trading centres.

As the trade boom increased the Vikings travelled further afield, across the Baltic Sea and along the Russian rivers. They founded more trading towns in Kyiv and Novgorod. The Viking traders even went as far as Istanbul – the capital of the mighty Byzantine Empire across the Black Sea. This perilous journey was one only the Vikings dared attempt, through vicious rapids and battling hostile natives. The Vikings continued their trading journey inland, bringing their goods to Jerusalem and Baghdad. The lure of the Silk Road and the exotic riches of the East were too good to resist, and Vikings met with traders from the Far East in their trading centres in Russia, trading fur and slaves for silk and spices.

Silver coins were the most common form of payment, but this was unlike today's currency where different coins are worth a particular value. The coins were weighed in scales to determine their value – this is because a lot of coins were melted down and crafted into intricate and beautiful jewellery to trade on.

**Did you know?**
**Viking weddings were huge affairs and could last for over a week**

The great extent of the Viking trade network can be seen today in the hoards of silver coins, created in England, which have been found in Sweden, not to mention the 40,000 Arabic coins and the 38,000 German coins also uncovered there. Nordic bowls, Mediterranean silk and Baltic axe heads have even been discovered buried under English soil.

This vast and illustrious trade network attracted a wealth of eager and talented artists and craftsmen. Viking bead-makers would import glass from Western Europe to create an array of simple and decorative beads for the wealthy to adorn themselves with, while the ample supply of amber from the Baltic lands was fashioned into pendants and playing pieces. Skilled Viking craftsmen transformed their imported bronze into fine ornaments and mass-produced brooches, and deer antlers could even be used to make delicate and beautiful combs.

© Abigail Daker; Alamy

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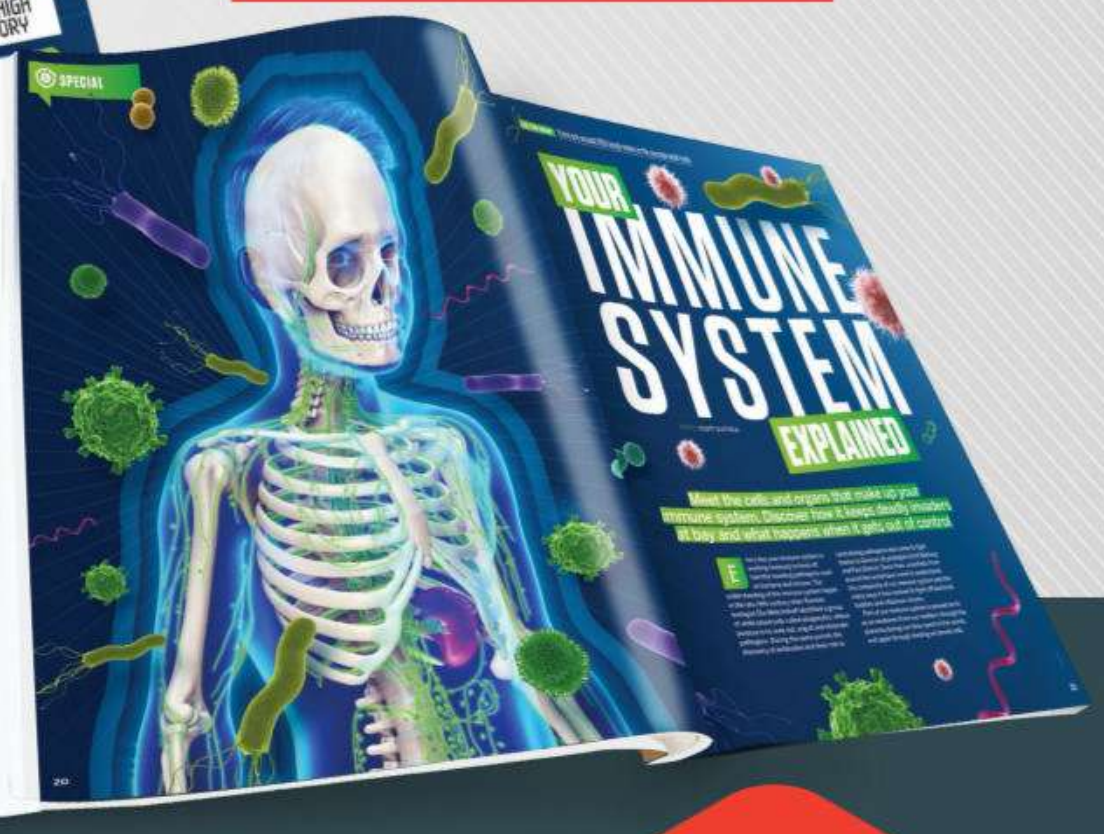


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# BRAINDUMP

Amazing answers to your curious questions

# Does it ever snow in Antarctica?

**Kraig Green**

Antarctica has an amazing climate. The coldest temperature ever recorded on Earth, -89.2 degrees Celsius, was captured here at the Russian Vostok research station. Such extreme cold brings out some unique and beautiful effects, such as 'diamond dust' – a shiny cloud at ground level made up of tiny ice crystals. And yes, it does snow. Antarctica is actually a desert, which means it doesn't snow very often. When it does, however, the snowstorms can be spectacular and terrifying.

## WHY AREN'T FEET MEASURED IN CENTIMETRES OR INCHES?

**@LadyLightning**

Feet, like any other part of our body, are measured in centimetres. If you're asking about why shoe sizes are in numbers, there's an interesting story to this. The standard way to do shoe sizes is to take three times the foot size in inches, and then take away 25, or 12 for kids' sizes. The reason for this complicated system is because shoes used to be measured not in inches or centimetres, but in an Old English unit called the 'barleycorn' that amounts to one-third of an inch.

## WHY AREN'T BUTTERFLIES BORN AS BUTTERFLIES?

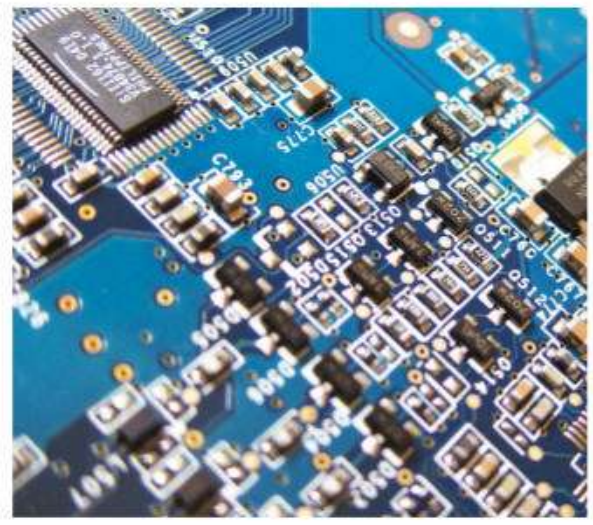
**Jessica Beales**

Nature has given butterflies the best adaptations not only for their survival, but also for the survival of other forms of life which depend on them. Butterflies pass through a four-stage life cycle: egg, caterpillar, chrysalis and butterfly. The caterpillar is the growing stage of a butterfly's life. Caterpillars are an important food source for lots of creatures. In the spring, birds feed them to their chicks, but caterpillars also form part of the diet of many other animals. All life on Earth is interdependent, so if butterflies were born as butterflies, many other forms of life would need different adaptations to survive.

## WHAT IS A SHORT CIRCUIT?

**Jonny Jackson**

People usually say 'short circuit' to mean any sort of electrical problem, but it's actually more specific than that. Suppose you have a light bulb connected to a battery. If the light is 'on', there's electricity flowing – coming out of the battery, going through the light bulb and then back into the battery. This is a circuit. A short circuit is when electricity doesn't take the path it was meant to – for example, if two bare wires touch. This causes a lot of electricity to surge at that point of contact, which causes the wires to get very hot.



**Did you know?**
Komodo dragons grow to around three metres long

## Are Komodo dragons venomous?

**Malcolm Baird**

It was once thought that the saliva of a Komodo dragon contained lots of harmful bacteria which, after being bitten, would infect the wound so rapidly that the prey would die within days of being attacked. But current research by herpetologists has shown that this giant lizard actually possesses a venom gland. The venom, which affects blood cells, is passed through ducts in between the teeth and transmitted to the prey via the saliva when they bite. Although many harmful bacteria are still present in the saliva, it's probably both the venom and bacteria combined that give this lizard its dangerous bite.

© Getty

# BRAINDUMP

## HOW DO FLOWERS PRODUCE A SCENT, AND WHAT'S IT MADE OF?

**Ayesha Riad**

Flowers produce scents via specialised glands located in their sepals, petals, labellum and body. The scents themselves are typically complex mixtures of low molecular weight and volatile compounds that, combined with the plant's shape and colour, are specially tailored to attract pollinating insects. The volatile compounds emitted from the flower act as multirange attractants, with their odour intensifying in relation to their proximity – this ability is especially important to plants that are largely pollinated by nocturnal insects. Interestingly, the scent of a flower varies in odour and intensity depending on the insect it wishes to attract, as well as its maturity. Plants that are commonly pollinated by bees and flies tend to have sweet scents, while those pollinated by beetles and larger insects produce the opposite, favouring musty odours.

**Did you know?**
The titan arum's flower smells like rotting flesh

## WHY IS BLUE-GREEN ALGAE DANGEROUS?

**Jenny Slater**

Blue-green algae can be dangerous when they produce chemicals that are harmful to humans and animals. Exposure is usually through untreated drinking water or recreational activities in lakes that have toxin-producing algae. They can produce skin irritants that lead to a rash after contact with contaminated water. The other two groups of harmful chemicals are classified as liver and neurotoxins because of how they affect the human body, and have led to incidents of human and animal poisoning worldwide. Even some fatalities have occurred after ingestion of very high toxin concentrations. It's also thought that long-term exposure can lead to chronic illnesses such as liver cancer. Blue-green algae can accumulate to high cell numbers – so-called harmful algae 'blooms' that often look like green scum floating on the surfaces of lakes. These blooms usually form in stagnant water in summer when temperatures are highest and when there are a lot of nutrients in the water. However, lakes and reservoirs used for drinking water and recreational activities are closely monitored to ensure there's no risk of poisoning.

## How long were sabre-toothed tigers' teeth?

**Chris Mahon**

Sabre-toothed tigers were actually sabre-toothed cats, or *Smilodon*, which lived mainly in the Americas and became extinct about 10,000 years ago. Their teeth were between 18 and 28 centimetres long. It's believed *Smilodon* used their teeth on subdued prey to cut off the blood supply and strangle them. Despite the larger teeth, they had a weaker bite than modern-day big cats, but they could open their jaws 120 degrees – a lion's limit is 60.

## WHY DO RATS HAVE SUCH BAD TEETH?

**Brian Dix**

Rats do not necessarily have bad teeth. However, as their prominent incisors constantly grow throughout their lifetime, the rodents often need to gnaw them down to prevent overgrowth – a process that can leave them looking uneven or discoloured. Importantly, though, despite their poor appearance, rats' teeth are highly specialised to maximise the environments they live in. The long, sharp incisors grant masterful levels of tearing and gnawing, while smaller molars enable torn food to be crushed prior to swallowing. Lastly, due to the harsh evolutionary pressures faced by the species, it can be argued that diverting energy resources to the perfection of teeth could limit their ability to survive day to day.

# What was the Parthenon in Athens used for?

**Jaxon Heston**

The Parthenon is the name given to the temple dedicated to the goddess Athena which stands on the Acropolis in Athens, Greece. It was built between 447 and 432 BCE and replaced an earlier unfinished temple that was destroyed by the Persians. It measures about 70 by 30 metres and is made of marble. The building project was part of a bigger scheme to beautify Athens initiated by the Athenian politician Pericles. The famous sculptor Phidias created a huge statue of Athena 10.5 metres high for one of the interior spaces of the Parthenon. The statue was made of gold and ivory and held a human-sized goddess of victory, Nike, in one hand. The carved stone sculptures that once decorated the temple were removed by Lord Elgin and sold to the British Museum in the 19th century.

## WHY DOES EARTH HAVE AIR?

**Alec Tait**

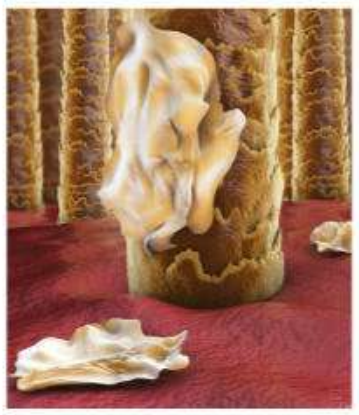
Earth has a key ingredient for life: water. As Earth's atmosphere was still forming, the first signs of life, in the form of microbes, emerged. This early life broke down carbon dioxide and produced oxygen. Mixed with nitrogen – its main ingredient – and argon, this makes up the mixture of gases we call 'air'. Gravity plays a key role in keeping the air in place. Other planets and moons that don't have gravity as strong as Earth can't keep an atmosphere, just as those with gravity too strong end up compressing theirs much more strongly.

© Getty

# What's the biggest shark, and is it the most dangerous?

**Paul Taylor**

The biggest shark in the world, reaching lengths of over 12 metres, is the whale shark (*Rhincodon typus*), but it's not the most dangerous. It feeds by filtering very small animals such as shrimps out of the water and has incredibly tiny teeth. The second-largest shark, the basking shark (*Cetorhinus maximus*), is also harmless to humans and feeds in the same way. Basking sharks are usually around 7.5 metres long. The largest, most dangerous shark is the great white shark (*Carcharodon carcharias*), which at its maximum size is less than half as long as a whale shark but has much bigger teeth – over five centimetres long. Great whites normally like to eat seals and other marine mammals, but have been implicated in hundreds of attacks on humans.



## WHAT IS DANDRUFF?

**Ayesha Riad**

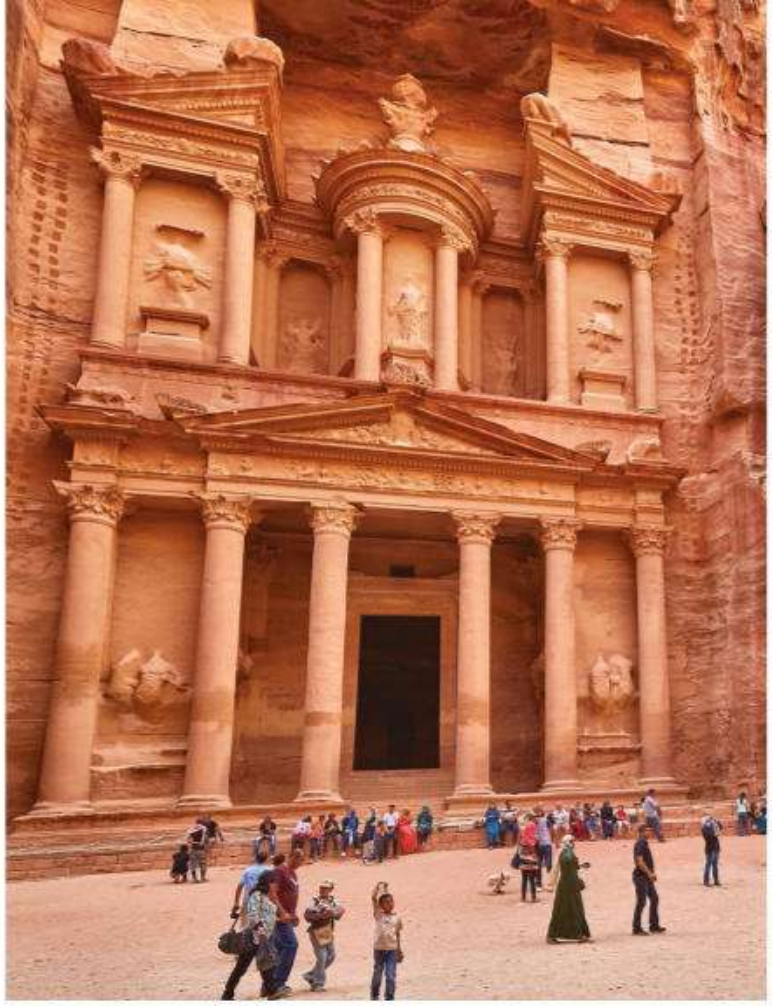
Dandruff is when dead skin cells fall off the scalp. This is normal, as our skin is always being renewed. About half the population of the world suffers from an excessive amount of this shedding, which can be triggered by things like temperature or the increased activity of a microorganism that normally lives in everyone's skin known as *Malassezia globosa*. Fortunately, dandruff is not contagious and there are many different treatments available, like specialised shampoo.

**Did you know?**
Whale sharks are filter feeders and can't bite or chew

# WHAT IS THE ARCHAEOLOGICAL SITE PETRA?

**Graham Jackson**

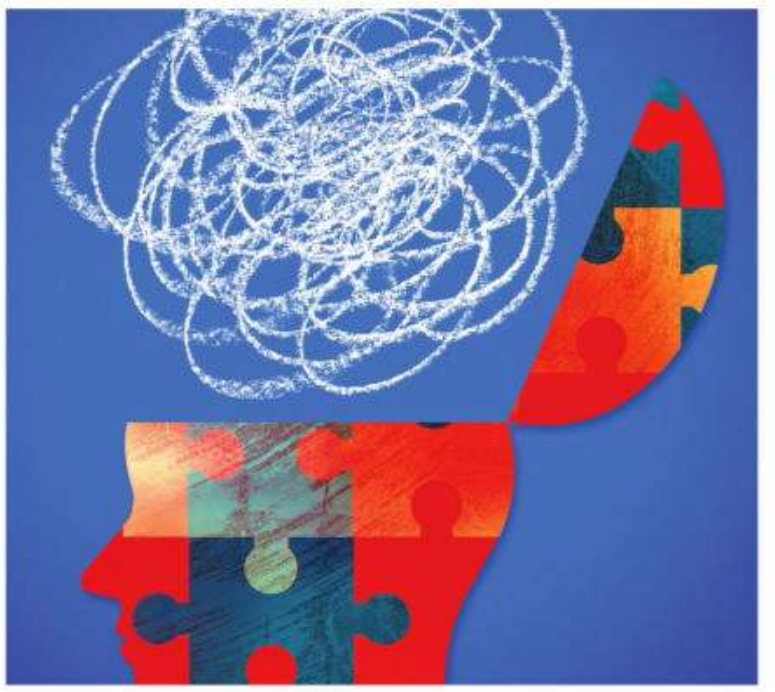
Petra is the name of the ancient city of a people called the Nabataeans. They lived in what is now Jordan in the Middle East. Petra stood at the crossroads of a number of major trade routes. In this desert environment, access to water is crucial. The people of Petra used a network of channels and cisterns to store rain water. The city grew rich from taxing high-value commodities like spices and silk. The people of Petra could afford expensive monumental tombs carved out of the red sandstone cliffs. These still survive and are a popular destination for tourists and the setting of films like *Indiana Jones and the Last Crusade*. Its importance waned after the 3rd century CE when it was caught up in the wars between Rome and its eastern enemies.

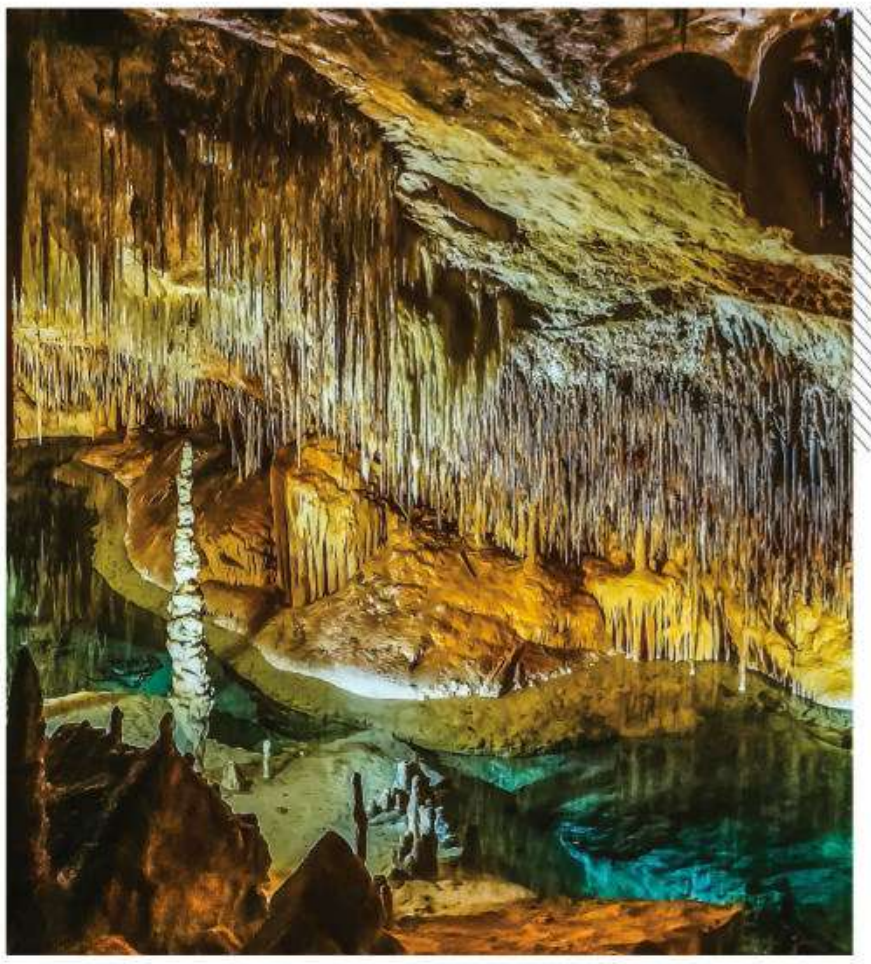


# WHAT IS CHAOS THEORY?

**Katrina Lucin**

Chaos theory is a mathematical way to study very complex systems. Quite often the events we observe around us depend on very tiny factors, and any small change in an initial event will lead to a totally different outcome. Imagine sneezing into the lottery machine during the draw and how that would affect other people. We find similar events all around us, from the weather to interactions between stars. The good thing is that we don't give up, and people are always trying to find patterns and underlying rules within this chaos. Fortunately, we also have computers to help researchers with their massive calculations.





# How do stalactites form?

**Claire Brevick**

Stalactites form by deposition of various minerals held within a water solution that slowly drips vertically from the ceiling of an underground cavern or structure. As the water droplets hang, they deposit contained minerals, often calcium carbonate. Continued downward growth in this manner is how a stalactite forms, or the reverse for stalagmites. The simplest stalactite form is a thin, hollow straw, but if excess water filters through or around the central body, then bulbous, tapered mineral cones can develop too.

# DID LADY GODIVA RIDE NAKED THROUGH THE STREETS OF COVENTRY?

**Ben Ashford**

Despite being entrenched in popular culture as a definitive event, this infamous ride probably didn't take place. If it did, Lady Godiva wasn't 'naked' in the modern-day sense. According to historical documentation, Lady Godiva – named Godgifu in Old English – was an Anglo-Saxon noblewoman and wife of Leofric, Earl of Mercia, in the 11th century. This is a certified fact, with Godiva mentioned in the *Domesday Book* of 1086 as one of a few women to remain significant landholders under the new Norman regime. Her legendary ride, however, isn't certified. According to the story, due to her husband's harsh taxation of the people of Coventry, Godiva appealed for him to remit the tolls until he agreed on the proviso that she ride naked through the city. She took her husband at his word. The first mention of this story originates in Roger of Wendover's *Flores Historiarum*, a much-disputed collection of anecdotes completed in the 14th century.

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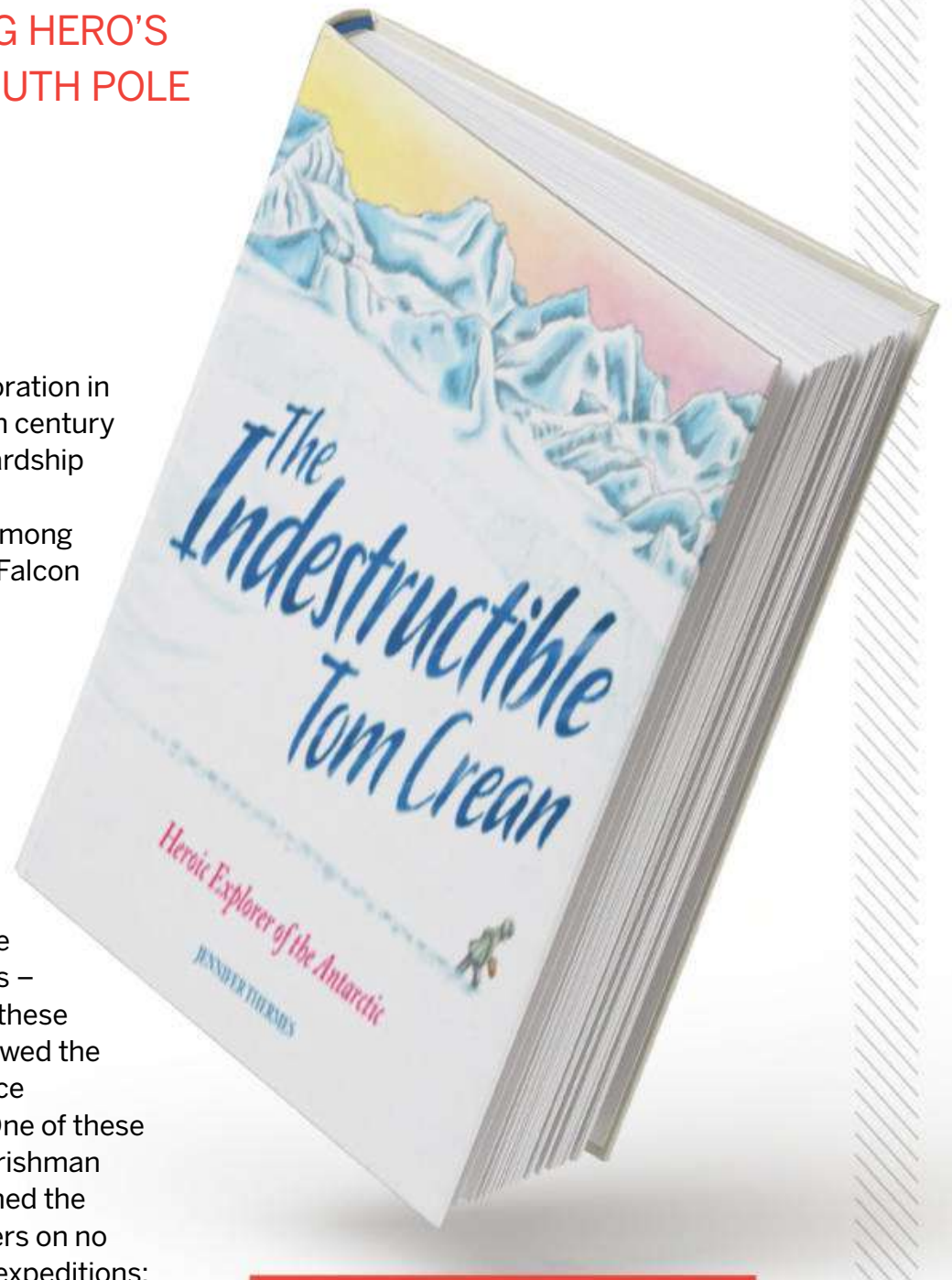
# THE LIBRARY

The latest book releases for curious minds

## THE INDESTRUCTIBLE TOM CREAN

THE TALE OF AN UNSUNG HERO'S ADVENTURES AT THE SOUTH POLE

AUTHOR AND ILLUSTRATOR **JENNIFER THERMES**
PUBLISHER **WELBECK**
PRICE **£7.99 / $19.99**
RELEASE **OUT NOW**

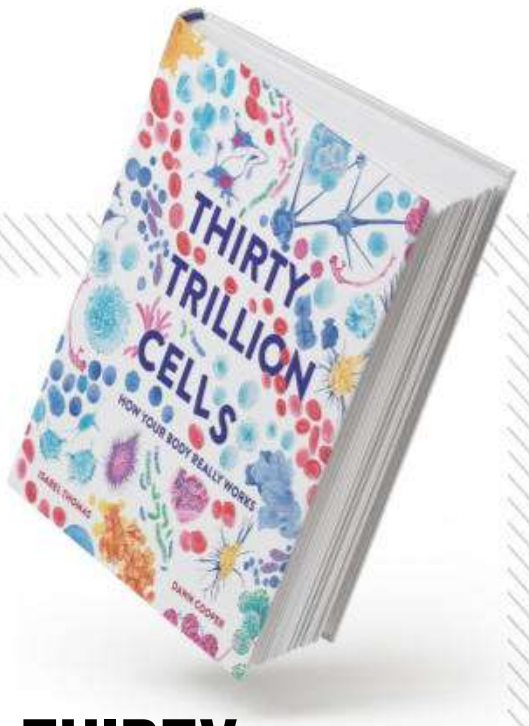



The age of Antarctic exploration in the early part of the 20th century is flush with stories of hardship and heroics from the southernmost point of our planet. Among the most famous explorers, Robert Falcon Scott, Ernest Shackleton and Roald Amundsen earned their stripes on multiple year-long expeditions to the South Pole in an era before reliable mechanisation and telecommunications could take the sting out of exploring the most remote and unexplored continent on Earth. How they prevailed rightly earned them accolades at the time and a place in the history books – though they were far from alone on these expeditions, as dozens of others crewed the ships and hauled supplies over the ice alongside a menagerie of animals. One of these unsung heroes was Tom Crean, an Irishman from a farming background who joined the navy and then accompanied explorers on no less than three of the most famous expeditions: on board the Discovery to begin with, followed by the Terra Nova and then the Endurance.

Among the many hardships they all faced on the unforgiving ice deserts of Antarctica, Crean twice survived falling through the ice into the bitterly cold water, being swept overboard into the ocean, starvation, malnutrition and a 35-mile solo journey to base camp by foot in a race against time to save his exhausted companions. And none of these trials that Crean endured were even part of the main expedition – he was a member of the crew sent to set up supply depots for the explorers ahead of their journey.

Tom Crean died in his native Ireland just before the outbreak of World War II without ever passing his stories on, though his crewmates, and especially those whose lives his heroics saved, certainly remembered him. As does author and illustrator Jennifer Thermes, who uses simple but effective language and a charming comic-book style to convey the perils of Antarctic exploration, as well as the tenacity and courage of the indestructible Tom Crean. It's a short but fantastic book that will likely endure at least as many read-throughs as its eponymous hero had adventures in the South Pole.

**"One of these unsung heroes was Tom Crean"**




## THIRTY TRILLION CELLS

HOW YOUR BODY REALLY WORKS

AUTHOR **ISABEL THOMAS**
ILLUSTRATOR **DAWN COOPER**
PUBLISHER **WELBECK**
PRICE **£14.99 / $16.95**
RELEASE **OUT NOW**

From the billions of neurons that give your brain power down to the garden of gut bacteria in your intestines, discover the 30 trillion cells that make up the remarkable human body in this creative children's book. Whether it's the complex immune system or the cardiovascular network, *Thirty Trillion Cells* condenses each aspect of your body's functions into language that's simple enough for a young audience to understand without skimping on the science. Each page is packed with information, annotated diagrams and step-by-step explanations to answer some of the most asked anatomical questions, such as how is bone made and where do cells come from?

What's so appealing about this book, and what will likely keep children laser-focused on its pages, are the wonderful illustrations on each page. White cell soldiers, a cardio percussionist and liver cell conveyor belts are just some of the intuitive ways that *Thirty Trillion Cells* illustrates how your body works.

# KING CHARLES

## THE STORY OF BRITAIN'S NEW MONARCH

AUTHOR **MARIA ISABEL SANCHEZ VEGARA**
ILLUSTRATOR **MATT HUNT**
PUBLISHER **FRANCES LINCOLN CHILDREN'S BOOKS**
PRICE **£9.99 / $15.99**
RELEASE **4 APRIL**

What does it mean to be king? For young children, the news of a new king can bring on a hoard of questions about the role and the royal family in general. This book holds many of those answers. Who is King Charles, and what events led to his crowning? As part of the Little People, Big Dreams series, this book tells the story of King Charles, from his birth to his coronation. The colourful, crayon-style illustrations on every page are expertly drawn so that the cartoons bear subtle resemblances to the real people. The artwork is a significant element of the book's charm as it tells the king's story in a way that will capture the attention of young readers.

When Charles was just three years old, his mother became the queen, making the toddler next in line to be king. *King Charles* helps children get to know the man behind the title. Did you know that when he was prince, Charles performed in plays and concerts, had a keen interest in the environment and created a charity to help young people excel? This story of King Charles' life is aspirational while still including essential harder-hitting details in a manner that children can understand. After reading this book, children will gain a better understanding of who the new king of the UK really is.

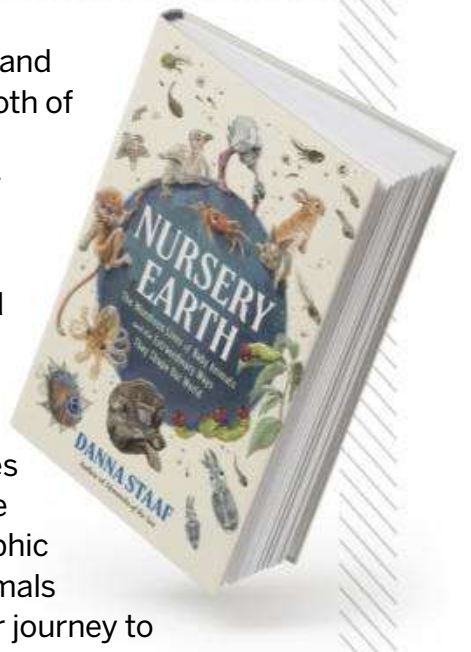
# NURSERY EARTH

## THE LIVES OF BABY ANIMALS AND THE WAYS THEY SHAPE OUR WORLD

AUTHOR **DANNA STAAF**
PUBLISHER **THE EXPERIMENT**
PRICE **£31.99 / $27.95**
RELEASE **6 JUNE**

Discover life in its infancy in this wonderfully enthusiastic title. From parasitic larvae to juvenile joeys, readers are taken on a tour of the world's nurseries to meet the cute, adorable and terrifying babies of the animal kingdom. You'll meet some of the most dedicated parents on the planet, but also some of the most deceptive, such as the cuckoo bird and marine mussels, both of which trick other animals into caring for their kids.

Along with the developmental and behavioural changes animals experience, *Nursery Earth* takes a deep dive into the physical metamorphic changes many animals experience on their journey to adulthood. This page turner is packed with stories of the most fascinating and unusual babies in nature, highlighting some of the amazing lives of many bird species and marine invertebrates. If you love learning about the lives of our wild neighbours and how their lives begin, then this book is a must read.




# HUMAN 2.0

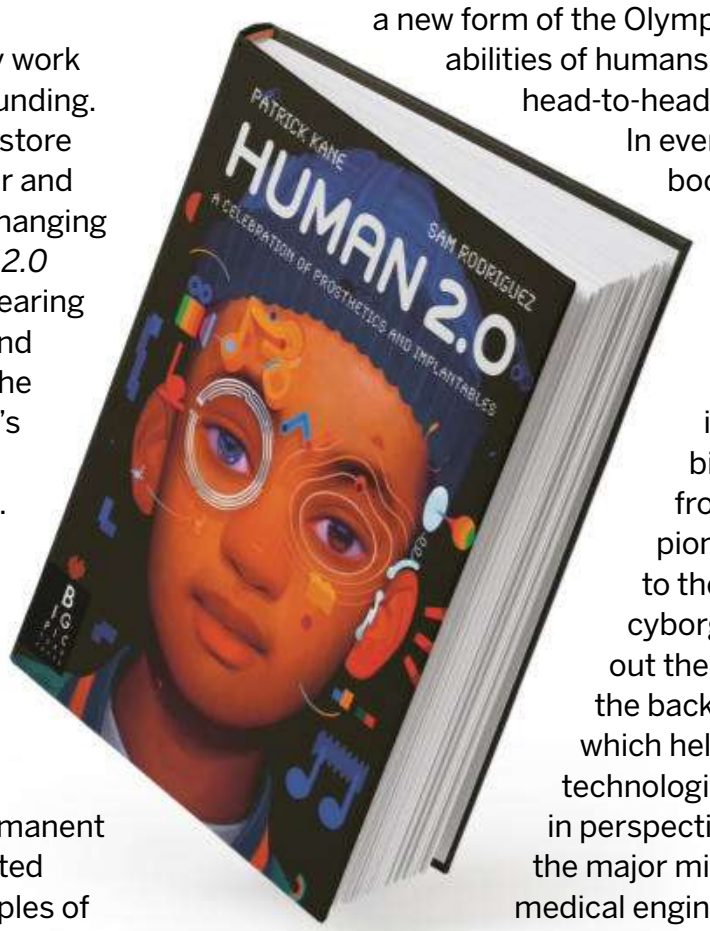
## A CELEBRATION OF HUMAN BIONICS

AUTHOR **PATRICK KANE**
ILLUSTRATOR **SAM RODRIGUEZ**
PUBLISHER **TEMPLAR PUBLISHING**
PRICE **£16.99 / $18.10**
RELEASE **30 MARCH**

When biology and technology work together, the results are astounding. Technology can be used to restore biological abilities on a cellular and mechanical level. Some life-changing examples featured in *Human 2.0* include adding the sense of hearing to the ears of a deaf person and balance and movement into the limbs of paraplegics. In today's world, a disability doesn't always have to be permanent. This book reveals the incredible advancements in human bionics since the first known prosthetic was worn over 3,500 years ago. It includes details of a variety of bionic body parts that are attached to the body and permanent implantable technology inserted through surgery. Some examples of implantable technology explored in this book are cochlear implants, pacemakers and implants in the brain.

The mood of *Human 2.0* is both optimistic and empowering. By focusing on the ever-evolving abilities of artificial limbs and intricate technologies, there seems no limit to any human's abilities. As well as learning about brain-controlled limbs, a man who changed his heart 26 times and sight-restoring bionic eyes, *Human 2.0* explores the events that test this technology to the extremes. You'll find out how a new form of the Olympics combines the abilities of humans and robotics in head-to-head events.

In every section of this book, creative illustrations add to its futuristic feel, ensuring the reader is totally immersed in the world of bionic technology: from the early pioneering prosthetics to the world's first cyborg. Be sure to check out the handy timeline at the back of the book, which helps put technological advancements in perspective and displays the major milestones of medical engineering.



# BRAIN GYM

Give your brain a puzzle workout

## Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

**EASY**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | | 1 | | | | | 4 | 6 |
| | 8 | | 2 | 5 | 6 | | 7 | 9 |
| 6 | 5 | | 7 | | | | 2 | |
| | | | 4 | | | 2 | 9 | |
| 7 | | 3 | | | 2 | | | |
| 5 | | | 6 | 8 | 9 | | | 7 |
| | 3 | | 1 | 9 | 5 | 4 | | 2 |
| | | | | 6 | | 7 | 3 | |
| 4 | 1 | 6 | 3 | 2 | | | 5 | |

**MEDIUM**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | | 6 | | 5 | | | | |
| 8 | | 5 | 2 | 6 | 1 | | | |
| | 7 | 9 | 3 | 4 | 8 | | | 2 |
| | 1 | 8 | | 3 | 2 | 4 | 6 | |
| | | | | | | 8 | | |
| | | 7 | 6 | | | | | |
| | 8 | | 1 | | | 9 | | 7 |
| | | | 5 | | 3 | | | 6 |
| | 9 | | | 7 | 4 | | | |

**HARD**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 4 | | | | 9 | | 2 |
| | | | | 9 | 1 | | | |
| 8 | | 5 | | | 7 | | 6 | |
| | 4 | | | | | 7 | | |
| 3 | | | | | | 1 | | |
| 7 | | | 4 | 5 | | | | |
| | | | 8 | | 9 | | | 5 |
| 9 | 7 | | | | | | | 6 |
| 1 | | | | | | 8 | 9 | |

## Word search

Find the following words

IMMUNE
PHAGOCYTE
VIKING
PORT
FROG
BEE
ORGAN
STOMACH
SPACESUIT
BOMB
ORBIT
EXPLODE

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O | R | B | A | N | W | O | T | E | O | R | B | I | T | Z |
| R | T | I | M | M | U | N | E | G | H | U | D | S | O | B |
| G | P | O | P | T | R | A | M | M | U | N | E | M | B | S |
| I | H | M | A | C | H | I | N | G | V | I | K | I | S | J |
| T | A | Q | V | T | K | F | R | O | L | S | T | R | O | P |
| E | G | A | N | B | V | I | X | K | P | O | R | M | M | O |
| E | O | J | F | R | O | R | G | A | N | O | Y | S | T | P |
| H | C | L | Y | E | A | M | C | R | B | U | B | V | F | U |
| S | Y | R | B | E | U | E | B | X | O | G | R | F | I | E |
| Z | T | Y | D | L | S | O | H | C | N | T | U | R | H | D |
| L | E | E | B | U | D | E | X | I | P | L | S | O | A | O |
| M | U | N | I | S | P | H | K | A | G | E | T | G | J | L |
| U | I | T | S | V | K | I | O | R | G | A | T | O | H | P |
| E | X | P | L | O | V | E | M | A | C | H | D | I | G | X |
| D | O | R | T | H | C | A | M | O | T | S | Z | X | R | E |

## What is it?

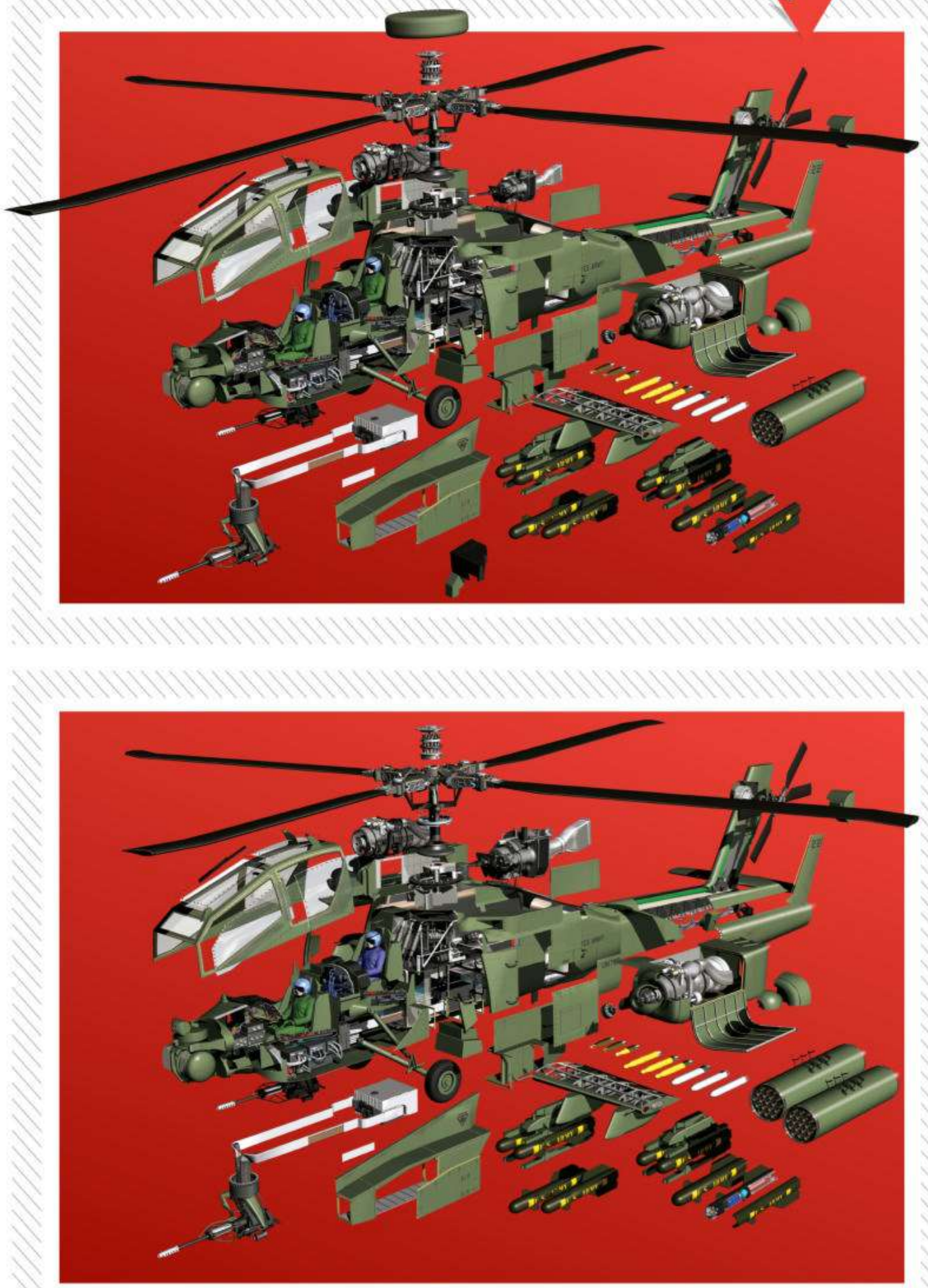
Hint:

It's no use to you any more

A

# Spot the difference

See if you can find all six changes between the images below



# QUICKFIRE QUESTIONS

**Q1 How many bones are in an adult human's body?**

- 66
- 126
- 186
- 206

**Q2 How long would it take to travel to the Sun at the speed of light?**

- Eight minutes
- 800 years
- 8 million years
- 8 light years

**Q3 How deep below Earth's surface is the core's centre?**

- 516 miles
- 3,958 miles
- 8,012 miles
- 12,458 miles

**Q4 Which is the farthest space probe from Earth?**

- Voyager 1
- Voyager 2
- Pioneer 5
- Messenger

**Q5 The global technology hub in California is called:**

- Iron Dell
- Mineral Vale
- Electric Gully
- Silicon Valley

**Q6 Which of these has Elon Musk not launched into space?**

- A rocket
- A car
- A satellite
- A chimpanzee

# Answers

Find the solutions to last issue's puzzle pages

**Q1** 1.255 SECONDS
**Q2** 17,600 MPH
**Q3** EINSTEIN
**Q4** 4,000
**Q5** BLUE
**Q6** 90 PER CENT

## What is it?

A PENNY

Spot the difference

© Getty

# HOW TO...

Practical projects to try at home

# MAKE A BEE HOTEL

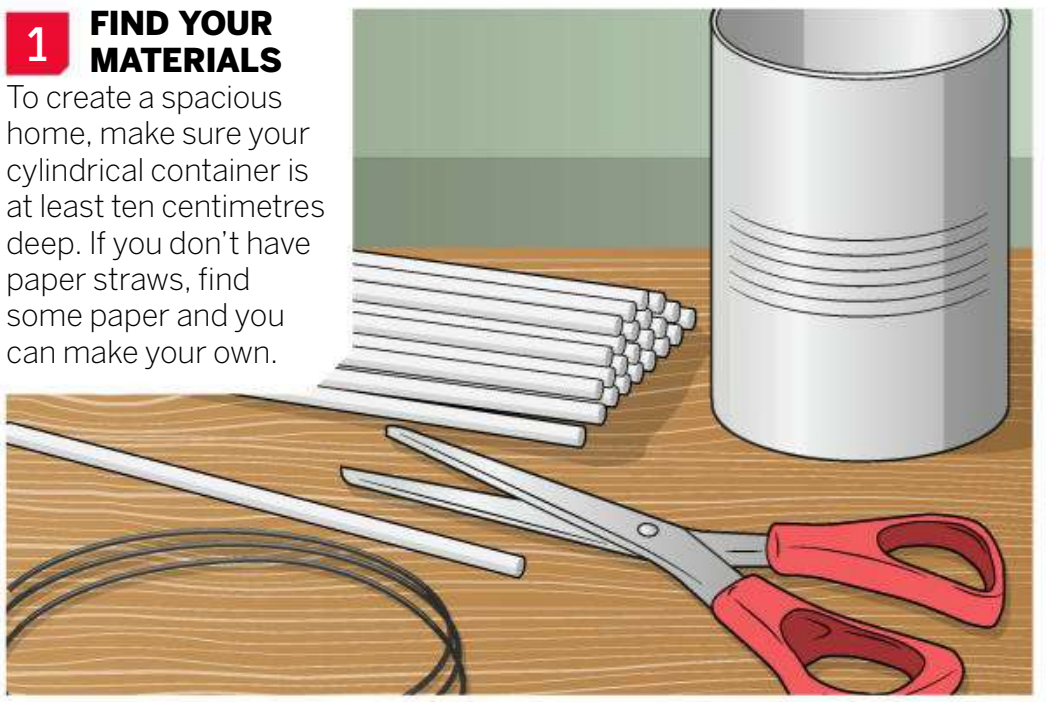
With these materials, you can help solitary bees find a place to call home

**KIT LIST**

- A large metal tin or other cylindrical waterproof container
- Paper straws
- String
- Scissors
- Low-VOC paint (optional)

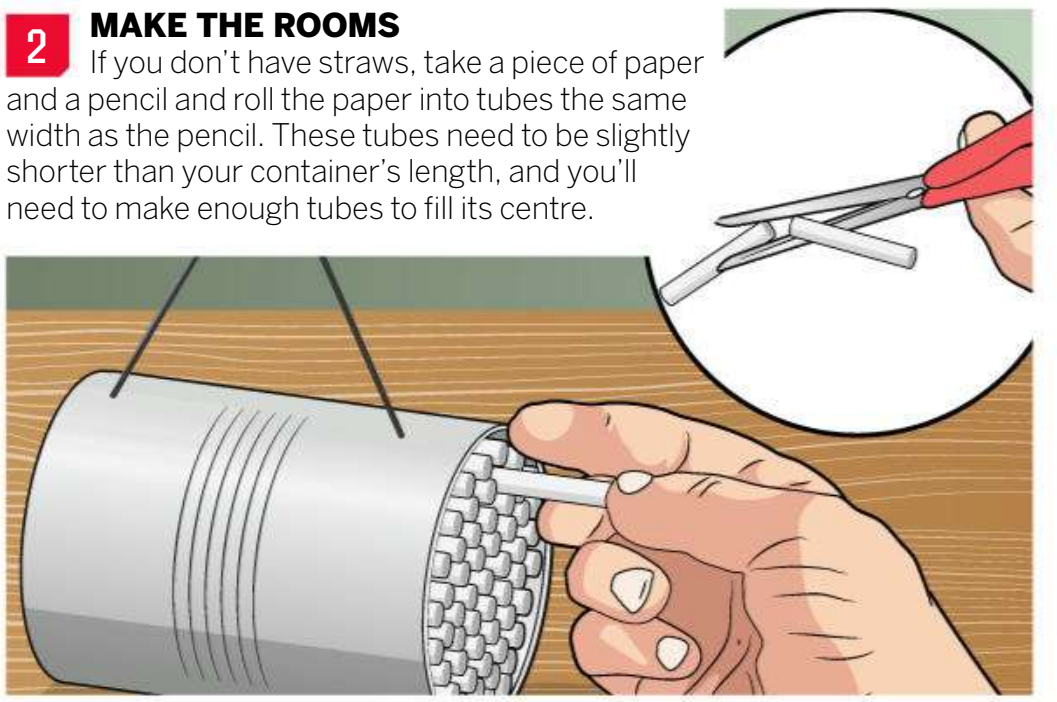
## 1 FIND YOUR MATERIALS

To create a spacious home, make sure your cylindrical container is at least ten centimetres deep. If you don't have paper straws, find some paper and you can make your own.



## 2 MAKE THE ROOMS

If you don't have straws, take a piece of paper and a pencil and roll the paper into tubes the same width as the pencil. These tubes need to be slightly shorter than your container's length, and you'll need to make enough tubes to fill its centre.

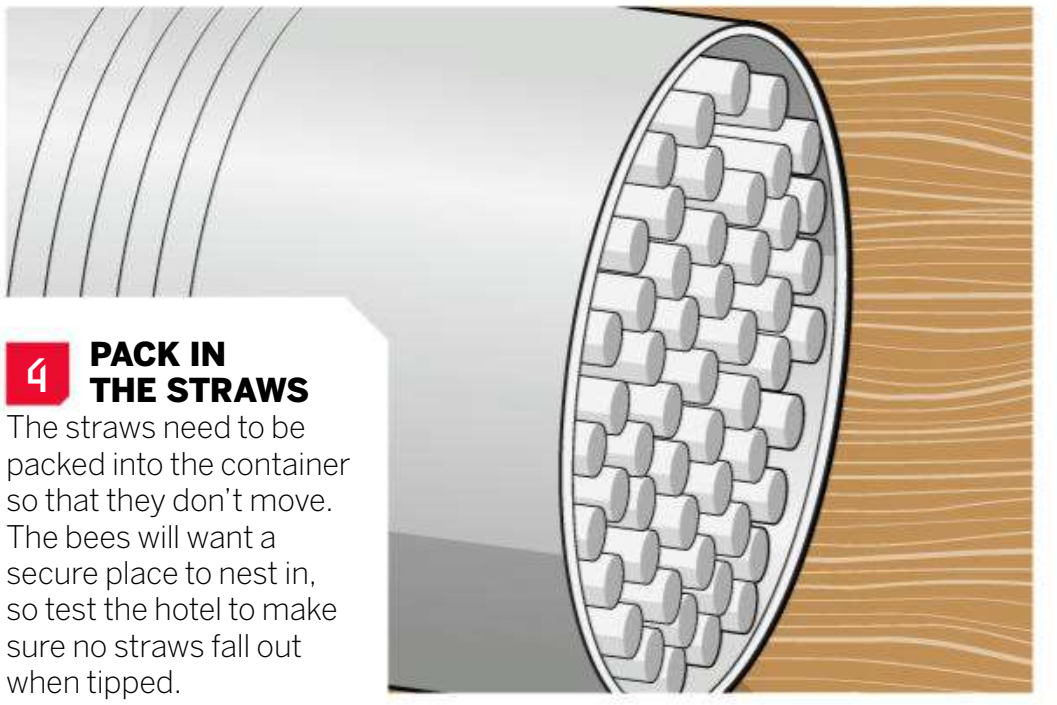


## 3 MEASURE THE RESIDENCE

Place a straw into the container and cut its end so that it's slightly shorter than it. This will stop wet weather from ruining the bees' homes. Use this straw as a guide and cut the other straws the same length.

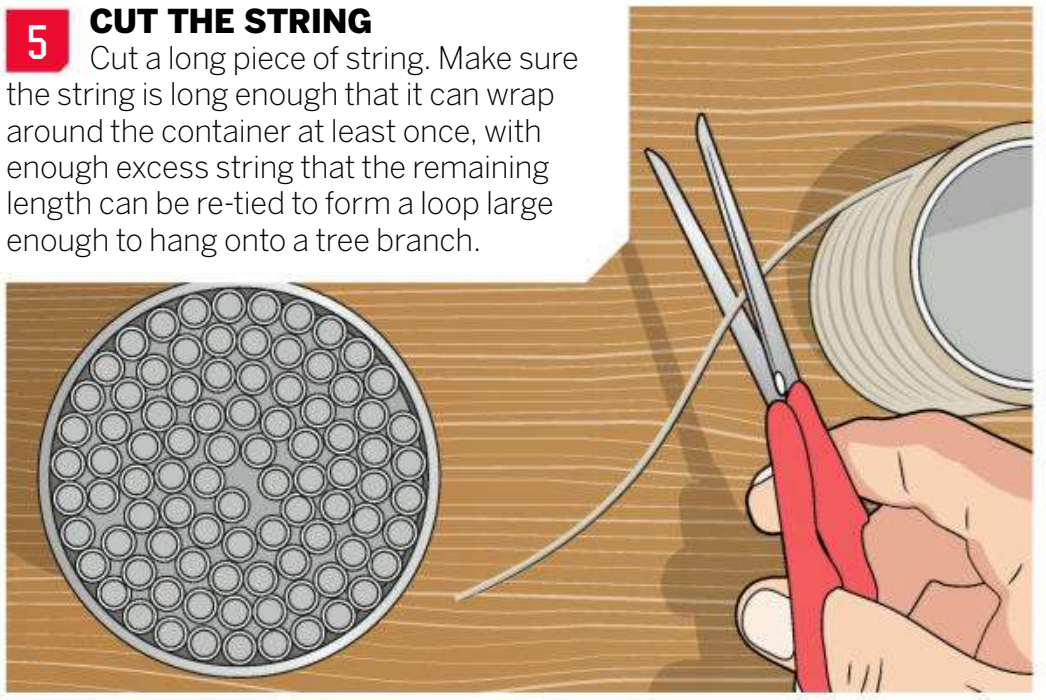
## 4 PACK IN THE STRAWS

The straws need to be packed into the container so that they don't move. The bees will want a secure place to nest in, so test the hotel to make sure no straws fall out when tipped.



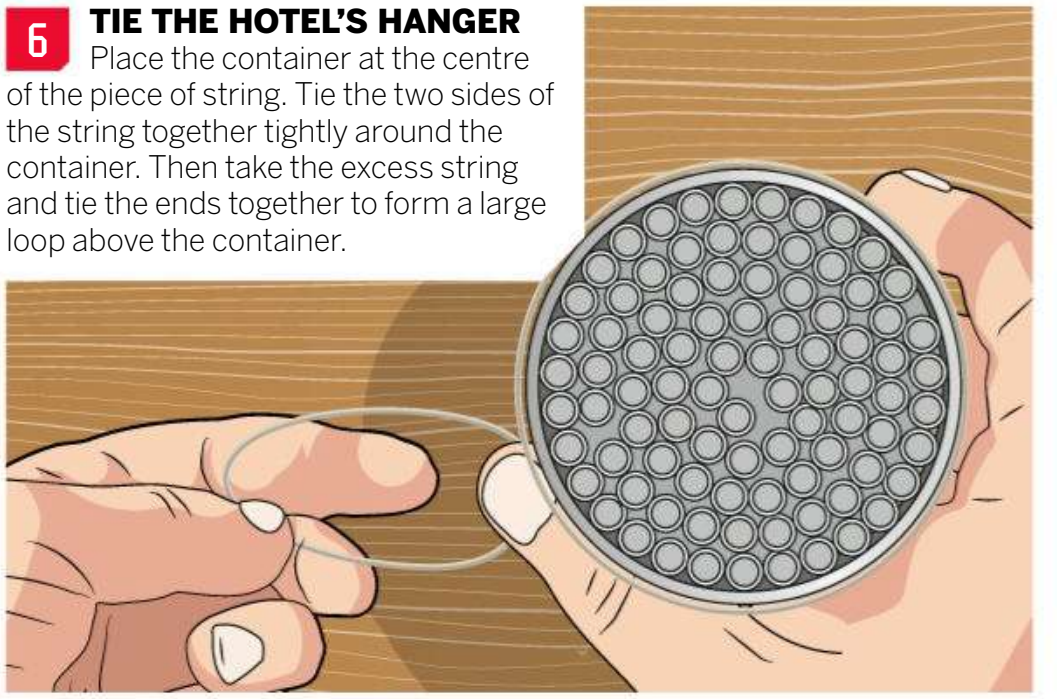
## 5 CUT THE STRING

Cut a long piece of string. Make sure the string is long enough that it can wrap around the container at least once, with enough excess string that the remaining length can be re-tied to form a loop large enough to hang onto a tree branch.



## 6 TIE THE HOTEL'S HANGER

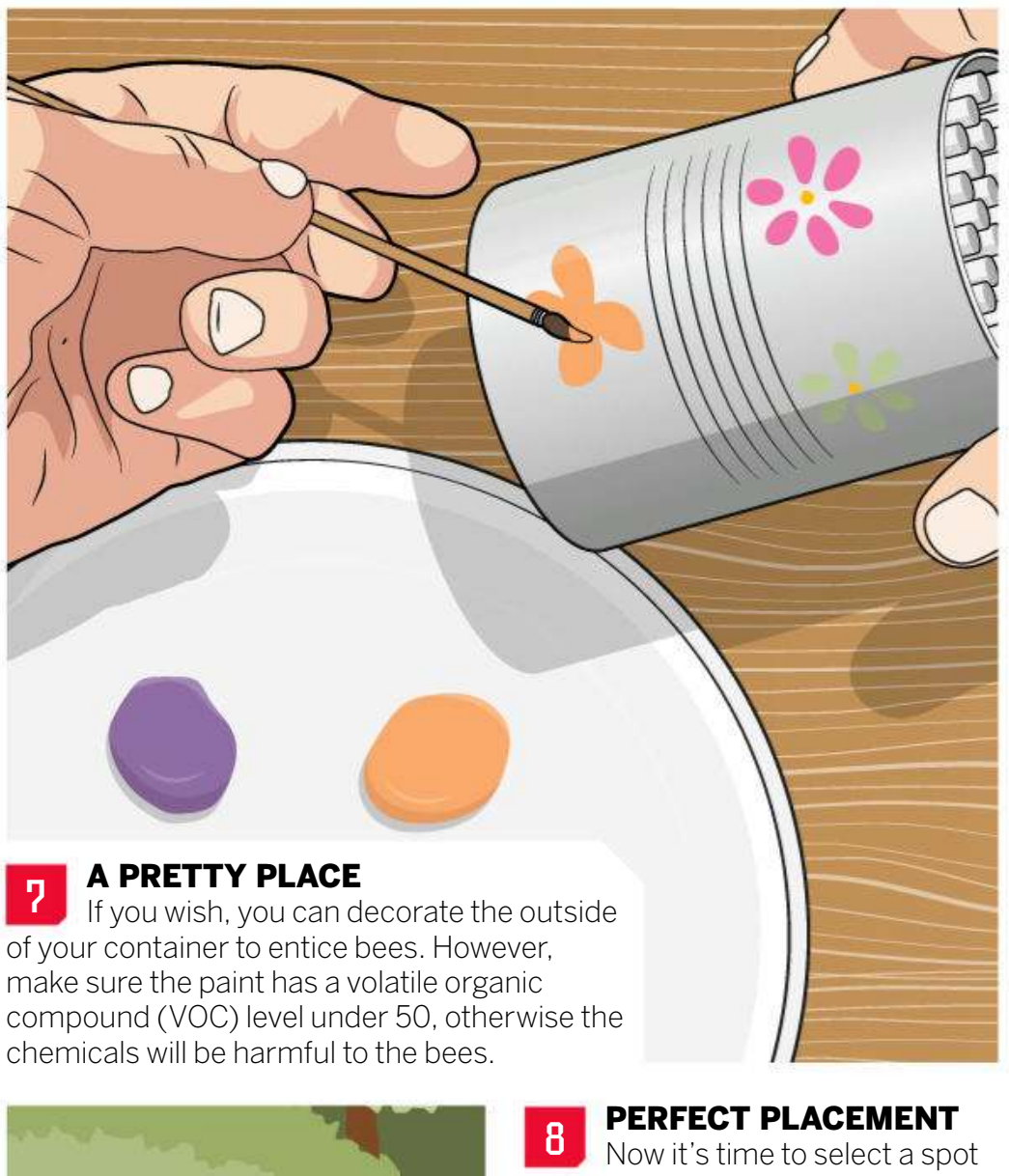
Place the container at the centre of the piece of string. Tie the two sides of the string together tightly around the container. Then take the excess string and tie the ends together to form a large loop above the container.



**NEXT ISSUE**
**LIGHTNING SPARK EXPERIMENT**

## DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you

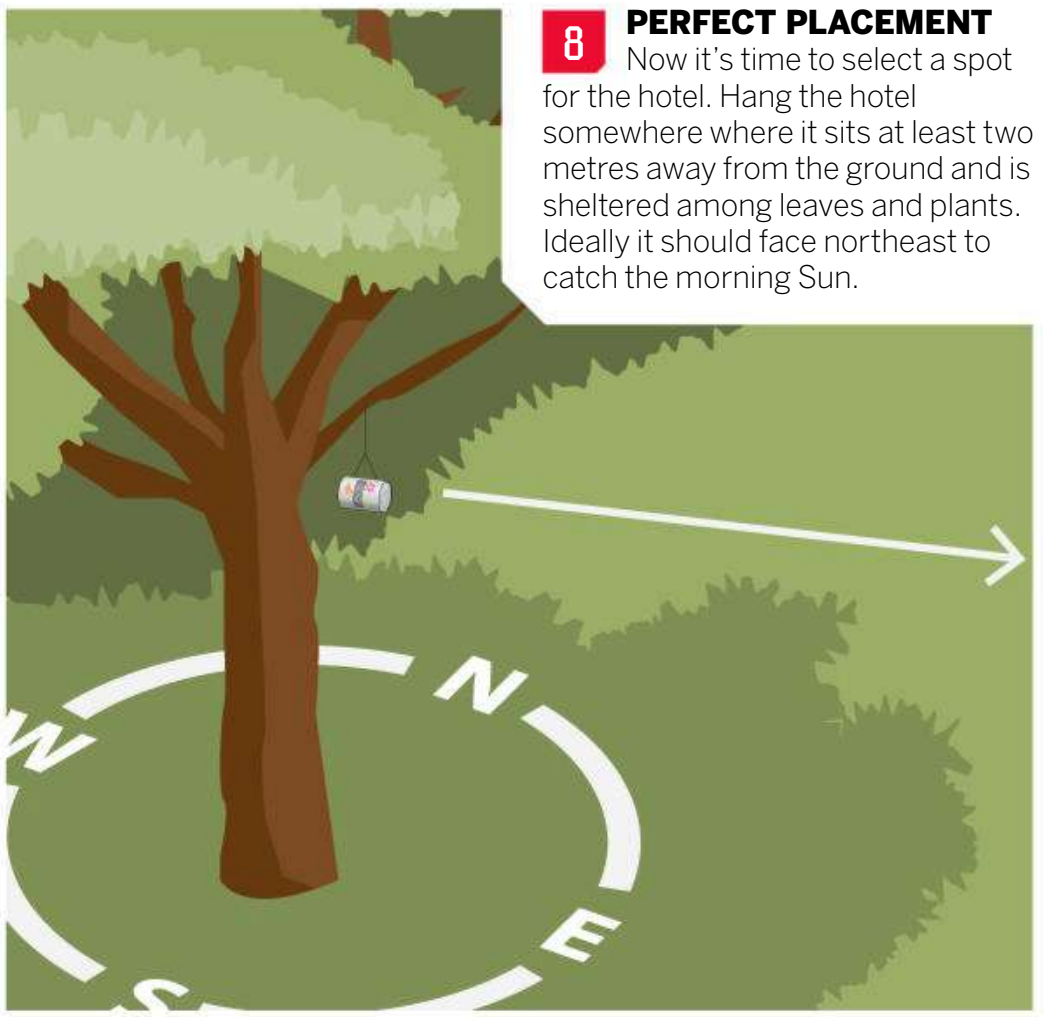


**7 A PRETTY PLACE**

If you wish, you can decorate the outside of your container to entice bees. However, make sure the paint has a volatile organic compound (VOC) level under 50, otherwise the chemicals will be harmful to the bees.

**8 PERFECT PLACEMENT**

Now it's time to select a spot for the hotel. Hang the hotel somewhere where it sits at least two metres away from the ground and is sheltered among leaves and plants. Ideally it should face northeast to catch the morning Sun.




### SUMMARY

**Some bees live as part of large colonies in extensive hives. But there are many species of solitary bees that seek small, safe cavities to nest in. This hotel provides the perfect space for solitary nesters, with individual compartments to host multiple bees. In urban areas, the reduced natural environment makes it difficult for bees to find homes. By creating a bee hotel and finding a suitable location, you're increasing their chances of survival while also providing an opportunity to observe the behaviour of these pollinators in your own space.**

**If your bee hotel proves successful, you'll likely notice many different bee species occupying the straw rooms. Some bees will make individual chambers along each straw using leaves to separate laid eggs. You should observe any hotel activity from a distance to make sure that the bees feel safe in their new home.**

## Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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# INBOX
Speak your mind



## EXPANDING UNIVERSE

Dear **HIW**,
I know that the universe is constantly expanding, but I don't understand how this works. Can you explain?
**Tegan Yiu**

**Thank you for your question, Tegan. The expanding universe is a tricky one to envisage because it's occurring on such a grand scale that we will never see it happening. Ever since the universe came into existence following the Big Bang, it has been expanding. Most other galaxies are moving away from ours, the Milky Way, all the time. This is because the Big Bang is effectively spreading the contents of the universe outwards as it expands, assisted by dark energy, which is actually speeding up the expansion.**

**A good way to visualise this is to think of the universe as a loaf of bread with raisins in it. The universe is represented by the dough, while each galaxy is represented by a raisin. As the bread is baked, the dough rises and expands outwards. Even though the bread is changing significantly, each raisin remains intact. The space between them increases as the raisins themselves stay mostly unchanged. Our galaxy is held together by forces such as gravity, so while the universe's rate of expansion is accelerating due to dark energy, conditions for our planet remain relatively constant, like the raisins in the loaf.**

The universe has been expanding and cooling since the Big Bang

LETTER of the MONTH

## WIN!
AN AMAZING PRIZE FOR LETTER OF THE MONTH
### INDESTRUCTIBLE TOM CREAN
**At the turn of the 20th century, scientists and explorers were in a race to unlock the secrets of the last great uncharted place on Earth: Antarctica. This is the true story of Tom Crean, a legendary Irish explorer**

## SPY BALLOON SAGA

Dear **HIW**,
I've been following the Chinese spy balloon saga and wonder about how these balloons operate?
**Nigel Watson**

**News of a Chinese spy balloon being shot down by the US military at the beginning of February has captured the attention of many. The balloon was seen flying over the coast of South Carolina and was tracked for a while as it flew at an altitude of around 18,000 metres. More balloons have been spotted since, imaging the ground below. The US military claims that China was attempting to spy on American military bases, while Chinese officials say that balloons from scientific research simply ventured off-track. Spy balloons are relatively rare, as spy satellites are less of a target than a low-flying gas-filled balloon. An advantage to using balloons is that they fly much closer to Earth, giving cameras a clearer view of what's going on below. These balloons are usually very difficult to control and have to travel with the wind. The spy balloon that made headlines had propellers, helping control navigation. This type can operate for weeks, but is sensitive to pressure changes and can burst as its altitude changes.**

Remnants of the shot-down spy balloon can be seen here

## EXPERIMENT SUCCESS

Dear **HIW**,
We tried the self-inflating balloon experiment. Please find attached the picture of the balloon.
**Sadagi**

**This looks great. It's always good to see results from How It Works experiments and we encourage all readers to send in images of any they've carried out. In issue 173 of How It Works, we showed you how to make a self-inflating balloon using baking soda and vinegar to learn all about acid-base reactions. We hope that you had fun watching the balloon expand before you and enjoyed exploring the science behind this chemical reaction.**

Sadagi's image shows what the experiment looks like when completed successfully

NEXT ISSUE
ISSUE 176
ON SALE 13 APR 2023
Available in print from all good newsagents and **magazinesdirect.com**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 24 (UK) and 83 (US).

Your muscles may swell for a few hours or days after a workout

# EXPANDING MUSCLES

Dear **HIW**,
When I do workouts, sometimes I find that my muscles go bigger for a few hours after working out, then go back to normal. Why does this happen, or is it in my head?
**Gregg McCulloch**

**This is a good question, as you will likely have been told that it takes time for your muscles to get bigger. So why does it look like they are bigger almost instantly? You'll be happy to know that it isn't in your head. However, what you are seeing isn't a growth in your muscles, but a swelling in the area as blood flow increases. When you exercise, your muscles need more oxygen, and so your blood vessels will dilate near your muscles. It's this that makes your muscles temporarily larger.**

The longest known prime number is 24,862,048 digits long

# PRIME IMPORTANCE

Dear **HIW**,
I don't like learning about prime numbers at school. Why do we need to know them and are they important outside of school?
**Jamie Gould**

**Prime numbers aren't the easiest topic in maths because there isn't an obvious pattern to follow in finding the next number in the series. Prime numbers are only divisible by themselves and one. They're essential in internet security. Two large prime numbers are multiplied together to get a very large number known as an encrypted code. This code can be publicly known on the internet because it would take too long for a person or computer to work out the original code and gain access to someone's private information.**

# WE ASKED YOU

**This month on social media, we asked you: If you could design the next spacesuit, what cool feature would you be sure to include?**

@DOODLE_NEWS
**Something like a grappling hook gun so I could float away safely and explore space in new ways**

@CYRUSTHEVIRUSYEETER
**A bottle opener on the wrist**

STEVEN H
**A device that lets people on Earth view what the astronaut is seeing through a VR headset**

NINA BOWEN
**A barefoot simulator, so you could feel what the ground would be like without the suit**

@GRANT_SHELDON
**Jetpack boots so you could fly around in space**

SARAH WOODROW
**Technology in the mask that displays details of what you're looking at**

© Getty / Sadagi Mushrif

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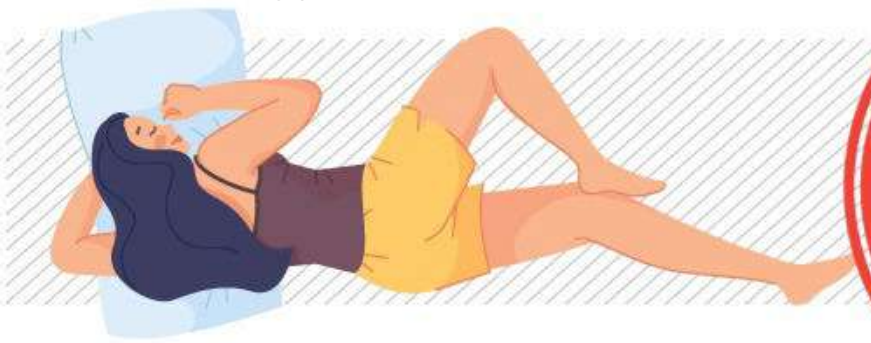
# FAST FACTS

Amazing trivia that will blow your mind

## 91 GIGABITS PER SECOND

NASA's ESnet internet speed is nearly 2,000 times faster than a typical UK broadband connection



**36**

The wren can sing three dozen notes in a second

## YOU'RE MORE LIKELY TO HAVE A NIGHTMARE IF YOU SLEEP ON YOUR LEFT-HAND SIDE

## 3 MILLION

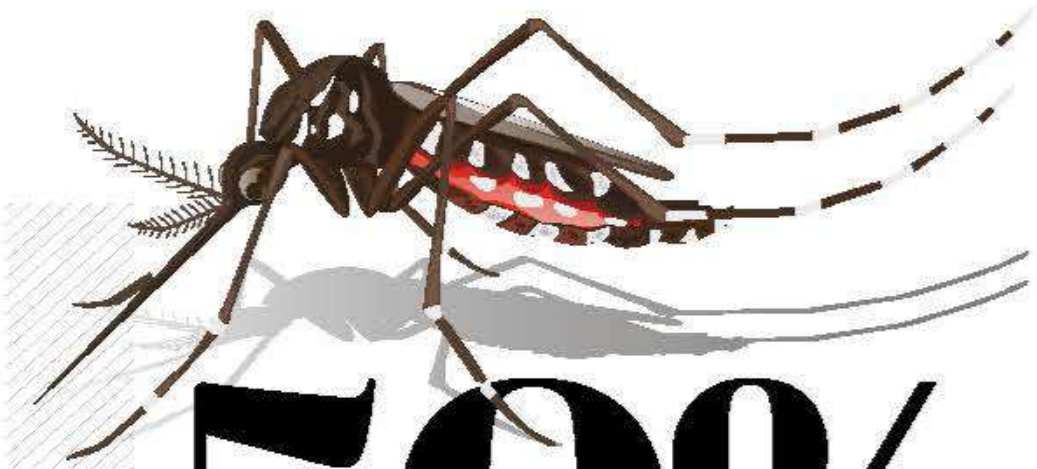
In Beijing, millions of chickens are tended to by robot nannies

## 1,000 YEARS

The trillions of plastic bags in circulation won't biodegrade until the end of the millennium

## 1365 BCE

Sculptor Bek took the first known selfie, carved in stone over 3,000 years ago



## 50%

Mosquitoes account for half of all human deaths across world history

## 47 MILES PER HOUR

The world's fastest elevator, in Guangzhou, China, took 43 seconds to travel to the 95th floor from the ground

**The word 'gasoline' has nothing to do with gas; it's derived from the surname of 19th-century oil importer John Cassell**

## STARFISH HAVE EYES ON THE TIPS OF THEIR ARMS

## 42 MINUTES, 12 SECONDS

**It would take less than an hour for you to fall through Earth to the other side**

© Getty

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